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Thermal Performance of Retrofit Exterior Insulation and Finish Systems on L-Shaped (Type 64) Barracks

by
Richard E. Rundus

This study tested and evaluated the energy performance and cost-effectiveness of retrofitting an exterior insulation and finish system (EIFS) to an uninsulated Type 64 (L-shaped) barracks that was normally operated and maintained.

A test-reference comparison was established at Fort Carson, CO, between an EIFS retrofitted barracks and a nonretrofitted control building. The two buildings were instrumented and energy performance data were gathered for a 1-year period to identify any energy savings attributable to the retrofit package.

Test results indicate that the EIFS retrofit may be cost-effective on barracks in similar climates where general maintenance practices have been improved and the building heating, air-conditioning, and control systems are properly designed, operated, and maintained. Economic analysis of test results for the improved operations indicated that a properly operating L-shaped barracks can be a candidate for a cost-effective EIFS retrofit based on the current costs for building retrofit and escalating energy costs.

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FOREWORD

This research was performed by the Energy and Utility Systems Division (FE) of the Infrastructure Laboratory (FL), U.S. Army Construction Engineering Research Laboratories (USACERL) for the U.S. Army Center for Public Works (USACPW). The work was completed under the Facilities Engineering Applications Program (FEAP) Project "Improved Thermal Efficiency of Existing Buildings." The USACPW technical monitor was B. Wasserman, CECPW-FU. Dr. David M. Joncich is Chief, CECER-FE, and Alan W. Moore is Acting Chief, CECER-FL.

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1 INTRODUCTION

Background

Standard barracks designs are found on most Army installations. These barracks have similar floor plans, construction materials, mechanical systems, and functions, with minor modifications for site-specific requirements. The L-shaped (Type 64) barracks building is very common on Army installations, with 399 of them currently in the Army inventory (Hittle, O'Brien, and Percivall 1983).

The L-shaped barracks were built around 1945. Because energy was cheap and plentiful, they were constructed with little emphasis on energy-efficient design or materials. Most of these buildings have uninsulated concrete masonry unit (CMU) block walls with continuous single-pane windows between the concrete pilasters. These uninsulated buildings were identified as potential candidates for standard energy conservation retrofits.

These retrofits could be applied to all buildings of a particular design and in a specific geographic region where the energy savings and payback meet the Energy Conservation Investment Program (ECIP) criteria (Office of the Chief of Engineers, 25 April 1988). The standardization of energy-saving retrofits could significantly reduce design and construction costs. The Army would also benefit from the potential economies of scale through quantity procurement of standardized energy conservation systems for a large group of buildings. In addition, the familiarity with operation and maintenance (O&M) of a particular retrofit would minimize O&M costs.

The U.S. Army Construction Engineering Research Laboratory (USACERL) has evaluated the potential energy savings for the type 64 barracks, along with four other standard Army designs, for a variety of energy conservation opportunities (ECOs). These ECAs were evaluated using the Building Loads Analysis and System Thermodynamics Program (BLAST) (Hittle 1979; Herron, Walton, and Lawrie 1981) for the standard building types in five climatic regions. This analysis generated a list of standard energy conservation retrofit packages for the various buildings (Hittle, O'Brien, and Percivall).

The L-shaped barracks showed the greatest energy savings with the exterior insulation and finish system (EIFS) retrofit for the climatic zone that includes Colorado Springs, CO. These savings were based on FY85 project year construction cost estimates and BLAST modeled energy consumption predictions.

The EIFS retrofit is a building envelope modification that covers all exterior walls with a layer of insulation and a protective cementitious base coat and "stucco-type" finish to improve the overall envelope thermal performance. EIFS provides the best energy savings and a savings-to-investment ratio (SIR) equal to or greater than one for buildings located in climates with annual heating degree day (HDD) totals greater than 5000 (Hittle, O'Brien, and Percivall). Based on the BLAST study, EIFS is not an economically supportable retrofit for buildings located in climates with annual cooling degree day (CDD) totals greater than 2000 or for locations with less than 5000 HDD.

Before recommending the EIFS retrofit be implemented on all previously uninsulated type 64 barracks Army-wide based only on theoretical savings, these claimed savings needed to be validated through a small-scale field demonstration. This demonstration would ensure that anticipated savings (and

thus the validity of recommending the retrofit) will be realized. If the energy savings and retrofit costs do not match those predicted by Hittle et al., then appropriate modifications can be made to the design and implementation procedures to reflect the true cost-to-benefit ratio realized in the field demonstration.

Objective

The objective of this work was to field-test and demonstrate the energy savings possible, if any, for uninsulated L-shaped barracks on Army installations by (1) retrofitting an EIFS to a least life-cycle cost (LCC) level and (2) measuring the actual energy savings resulting from the improved building envelope thermal efficiency.

Approach

The demonstration was conducted as follows:

1. Technical Report (TR) E-183 was reviewed to identify building categories and locations that showed the greatest theoretical potential for meeting ECIP criteria for a cost-effective EIFS retrofit.

2. An L-shaped (Type 64) barracks building was selected for the EIFS retrofit.

3. Fort Carson, CO was selected as the site for the field validation experiment.

4. Building 812 was selected for the EIFS retrofit. Building 813, an identical L-shaped barracks located adjacent to 812, was selected as a nonretrofitted control building for the experiment.

5. Energy metering and data acquisition equipment was installed in buildings 812 and 813 to record energy usage and building loads, including representative interior and exterior temperatures.

6. The EIFS was installed on Building 812.

7. The retrofit and control buildings were monitored through a complete heating season.

8. Energy performance data were compared between the two buildings to determine actual energy savings attributable to the EIFS. A detailed energy data analysis was performed in an attempt to accurately model the EIFS energy impact on L-shaped barracks.

9. An economic analysis was performed on the energy savings data to determine the actual LCC effectiveness of the EIFS. This information was compared with the predicted savings reported in TR E-183.

Scope

This report describes items 1 through 4 and 6 through 9 in the **Approach**. Item 5 is reviewed briefly, but is covered in much greater detail in Interim Report E-88/08 (Westervelt, Northrup, and Allen 1988).

Mode of Technology Transfer

Information from this study has been included in *DEH Digest* articles and in an Engineer Technical Note (ETN). Revisions have been made to Corps of Engineers Guide Specification (CEGS) 07240 *Exterior Insulation and Finish System*, and a technical manual for EIFS selection and installation will be written.

2 BENEFITS OF EIFS ON L-SHAPED BARRACKS

Theoretical Energy Reduction

The BLAST computer modeling of the expected energy savings for retrofit EIFS on previously uninsulated type 64 barracks suggested that the total annual heating energy reduction would be 19 percent, or 800 MBtu for the Colorado Springs, CO climatic region (Hittle, O'Brien, and Percivall). This reduction would represent about an 11 percent reduction in total annual building energy consumption. The computer model indicated that the average total annual energy savings for all five climatic regions considered would be 540 MBtu/year, or an annual energy reduction of 7.8 percent.

Table 1 shows theoretical (based on the BLAST model) energy savings projected for the EIFS retrofit in the five climatic regions. The percentage energy reduction column reflects the predicted annual heating energy reduction as a percentage of the total preretrofit annual energy consumption (including electricity). Although all sites indicate energy savings potential, the actual construction costs may far outweigh the energy savings potential over the useful life of the facility.

Additional Benefits

The EIFS retrofit will provide other improvements to the buildings' O&M in addition to anticipated energy savings. For example, building exterior appearance will be greatly improved compared with the painted CMU walls. Such an improvement meets the Army Communities of Excellence (ACOE) program objective for upgrading the physical environment (Department of the Army, 1988). The EIFS will reduce or nearly eliminate the requirement for exterior painting, which typically occurs every 6 to 12 years, with an average repainting schedule of every 8 years (Neathammer, Neely, and Stirn 1989). Other exterior CMU wall maintenance should be eliminated, as well, while occupant comfort and morale will be improved.

Table 1

BLAST Predicted Energy Savings for Type 64 Barracks With EIFS Retrofit

		Annual Gas Consumption		Reduction	
		Before	After	MMBtu	Percent
HDD*	Location	MMBtu			
6415	Colorado Springs, CO	7315	6515	800	17.6
5007	Columbia, MO	7713	7059	654	13.7
3579	Raleigh, NC	6955	6472	483	9.8
1390	Phoenix, AZ	5992	5639	353	3.8
2387	Fort Worth, TX	6538	6127	411	6.5

*Heating degree days.

Even if the EIFS retrofit is not a cost-effective energy conservation alternative for type 64 barracks, the project will provide the following benefits in addition to the improved esthetics:

- A demonstration of the actual energy savings that can be expected from an EIFS retrofitted barracks under typical field O&M practices.

- Insight into additional conditions or actions necessary for the EIFS to be an effective energy-saving treatment.

- Detailed data on current energy usage patterns and trends for an L-shaped barracks building as typically operated and maintained at Fort Carson.

- Building energy performance data that will allow a determination of energy cost levels necessary to make the EIFS retrofit a cost-effective energy conservation measure.

- Permanent installation of gas, electric, and water metering equipment and a complete data acquisition system for monitoring building energy performance for any future studies.

Building Description

The L-shaped, type 64 barracks was identified in the earlier BLAST study as a potential candidate for the EIFS retrofit. The barracks were built around 1945. Total floor area is 38,000 sq ft. Total exterior wall area is 14,916 sq ft with 7990 sq ft of single-glazed windows.

The barracks is a three-story building with exterior walls constructed of 8-in. CMU block. The floors and main support structure are poured concrete. The roof is constructed of 0.5-in. ballast stone, 2 in. insulation, and 2 in. concrete with an air space and ceiling tile below it.

On the south end of the buildings being tested, a one-story section is attached which makes the plan view look like the letter "L." This single-story section was originally used as an attached mess hall. The two companies that occupy the buildings at Fort Carson now use the area for offices and conference rooms. The barracks has single-pane, double-hung windows on all perimeter room walls. Figures 1 and 2 show the EIFS retrofit L-shaped barracks and the nonretrofitted control/reference building, respectively.

The three-story barracks section was originally designed as open-bay living area for troops. The second and third floors are divided into rooms that house two enlisted personnel each. There are typically three bathrooms with laundry facilities and showers on each floor. The first floor has been modified to provide some additional offices as well as recreational areas and three-person noncommissioned officer rooms with separate bathrooms. Figure 3 is a general floor plan of the first floor of the L-shaped barracks.

The rooms are cooled by individual ceiling-mounted fan coil units. Chilled water is provided from a central chiller plant to the individual barracks. The heating system was not modified when the open bays were divided into semiprivate rooms. It consists of baseboard-mounted free convection heaters, two 50-MMBtu/hr boilers, three steam-to-hot-water converters (one for each of three zones), and appropriate plumbing and controls. Baseboard heating is located on the perimeter walls of all rooms in the three-story barracks wing. The heating hot water is pumped from the converters to the perimeter baseboard heaters through a two-pipe heating loop. The baseboard heating loops run through 8 to 15 rooms before returning to the main return water header and back to the steam-to-hot-water converter located in the mechanical room.

Figure 1. Building 812: Type 64 (L-shaped) Barracks With EIFS Installed.

Figure 2. Control/Reference Building 813.

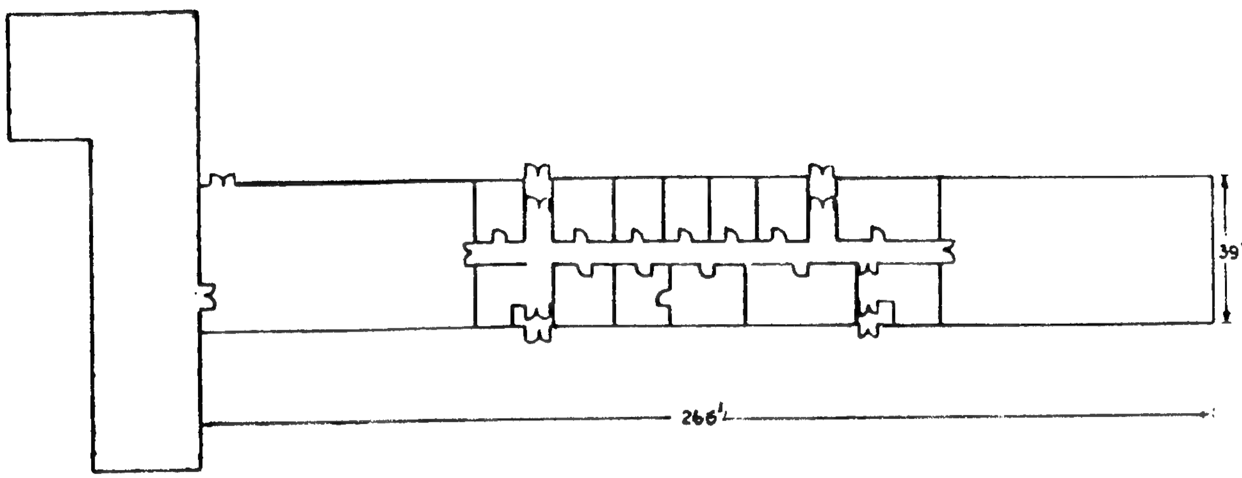


Figure 3. Floor Plan: L-Shaped Barracks (First Floor, General).

The temperature of the hot water supply to the baseboard heaters is set by a manually adjustable controller which maintains a *fixed* supply water temperature. This water temperature is *not* reset based on outside air temperature (OAT). If the OAT exceeds an adjustable setpoint temperature (typically 55 °F), the zone hot water supply pumps are turned off. However, the boiler continues to maintain adequate steam pressure to the converters throughout the heating season; the zone supply water temperature controllers modulate the steam valves to the converters to maintain the supply water temperature, regardless of OAT. The heating control system has no direct feedback from the occupied zones and is not reset based on zone loads or OAT.

3 THE EIFS RETROFIT

Overview

EIFS are typically available as two types: polymer-based (Class PB) and polymer-modified (Class PM). (Occasionally, the term "hard coat" is used to describe polymer-modified EIFS and "soft coat" to describe polymer-based EIFS. These terms imply inaccuracies about the systems' mechanical properties, which are mainly dictated by the mechanical properties of the base coat. The Exterior Insulation Manufacturers Association (EIMA) has defined the differences between polymer-based and polymer-modified EIFS. To conform with current terminology, polymer-based EIFS should be referred to as "Class PB" and polymer-modified EIFS should be referred to as "Class PM.") The Class PB systems incorporate a molded expanded polystyrene (MEPS) insulation board (commonly referred to as "beadboard") as insulation material. The MEPS board is typically held to the building exterior with an adhesive. A protective base coat is applied to the outside of the MEPS board. This base coat may be a polymer-cement mix or all polymer-based and is typically reinforced with one or more layers of a polymer-coated glass fiber mesh. The thickness of the base coat ranges from 1/16 in. to 1/4 in. depending on the number of layers and type of reinforcing fabric used. The base coat protects the insulation from mechanical damage and weathering. An acrylic stucco-type finish coat is applied over the base coat and is available in a wide variety of textures and colors.

Class PM EIFSs differ from Class PB systems in several important ways. The Class PM systems incorporate an extruded expanded polystyrene (XEPS) insulation board that is mechanically fastened to the existing building structure. The XEPS board is then covered with a mesh material that is also anchored to the existing structure through the insulation board. This mesh is typically a fiberglass fabric that has been polymer-coated. The Class PM base coat is a polymer-modified cementitious mixture. The base coat is troweled into the fiberglass mesh. Chopped glass fibers may be incorporated into the base coat for additional reinforcement. The thickness of the Class PM base coat ranges from 1/4 in. to 3/8 in. An acrylic or cementitious finish coat is applied over the base coat. This finish coat is available in a wide variety of colors, textures, or aggregate finishes. Figure 4 shows the general application details and components for a Class PM system.

For further information on EIFS durability, design considerations, inspection, etc., refer to USACERL Technical Report M-91/02. "Exterior Insulation and Finish Systems (EIFS) on U.S. Army Facilities: Lessons Learned," October 1990.

Building 812 EIFS Retrofit

In the winter of 1986/87, building 812 had a Class PM EIFS installed. The system was manufactured by Insul/Crete Company, Inc. The Class PM system was selected because it matched the initial thermal performance requirements of an R-value of 5 per inch of insulation. Later study indicated that the Class PB system is typically selected since it is usually 30 percent less expensive. However, the MEPS insulation board only provides an R-value of 3.85 per inch.

The Insul/Crete system uses extruded polystyrene rigid insulation board manufactured by Dow Chemical Co. The insulation has an R-value of 5/in. of thickness. Two inches (R-value = 10) were installed on all block wall areas. One inch of insulation was installed on cement pilasters and other protruding building elements, such as window ledges, to create an esthetically pleasing exterior finish. The entire exterior of the barracks was treated with the EIFS except for the roof. The walls had insulation installed to ground level.

Since the retrofit was added during the winter, the contractor had to take special precautions in the installation procedure. Both the cementitious base coat and the finish coat had to be installed at ambient temperatures above 45 °F and maintained above that temperature for at least 24 hours. To achieve these conditions at the work site, the building walls and scaffolding were encased in sheets of plastic, and kerosene heaters were run continuously to ensure proper curing of the EIFS product.

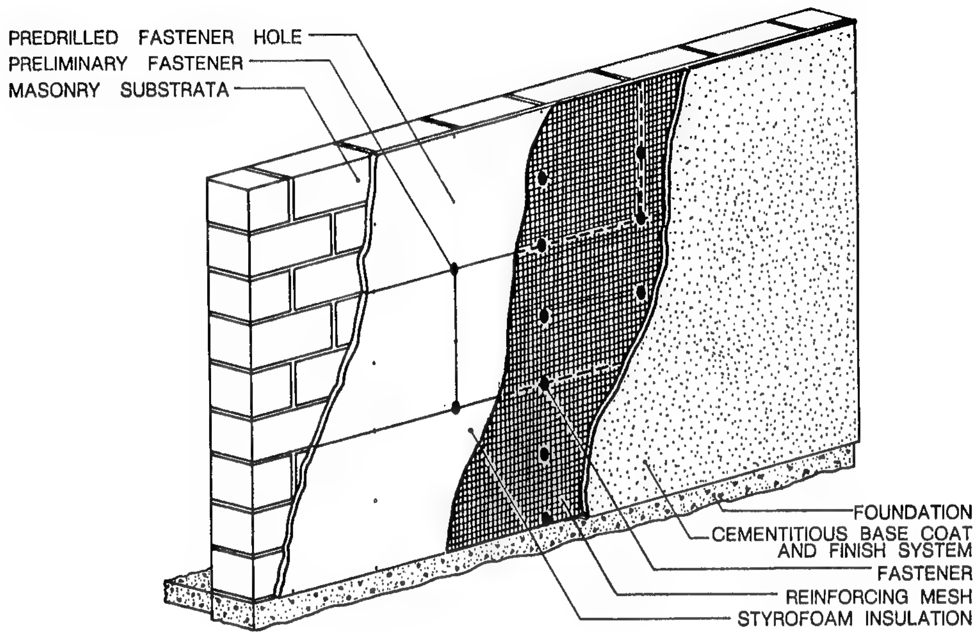


Figure 4. Application Detail for Class PM EIFS Over a CMU Block Wall.

4 EXPERIMENTAL SETUP AND PROCEDURE

A test-reference experiment was designed to evaluate the energy savings resulting from the EIFS retrofit to a type 64 (L-shaped) barracks. Building 812 at Fort Carson was selected to receive the EIFS retrofit for testing. Building 813, located adjacent to 812, was not modified and was used as the reference or control building. Figures 1 and 2 show buildings 812 and 813, respectively. The experiment was designed such that energy use data were gathered simultaneously for both buildings. This arrangement allowed the energy performance for the two facilities to be compared directly with no compensation for variations in weather effects since both buildings experienced identical climatic conditions throughout the test.

As a result of the experimental design, the differences in energy consumption between the two barracks were assumed to be the result of the EIFS retrofit on building 812. Occupancy data were collected, when available, to allow compensation for significant differences between building use due to company elements leaving for extended field maneuvers.

Domestic hot water (DHW) consumption was metered and also used as an indicator of building occupancy. In addition to DHW, seven interior temperatures were monitored along with total building gas and electrical energy consumption, OAT, and heating energy delivered to each of three zones. The data set designed for the barracks was chosen to allow monitoring of all pertinent building energy consumption parameters, including mechanical system components' energy usage. This data set contained a variety of measured variables that allowed the validity of the data to be readily cross checked for accuracy. The data set also gave some indication of the buildings' operational state. Interim Report E-88/08 (Westervelt, Northrup, and Allen) describes the selection of data acquisition equipment and monitored energy performance parameters for the L-shaped barracks. Chapter 4 of that report provides detailed information on the data management, including data organization, software used, file management, and data quality assurance procedures.

5 DATA ANALYSIS AND RESULTS

Overview

The data loggers recorded hourly data files for building energy consumption parameters including interior space temperatures and OAT. Table 2 contains a complete list of variables included in the L-shaped barracks data set. The hourly data were periodically transmitted to USACERL for analysis. Details of the automated data transmittal protocol are discussed in Interim Report E-88/08.

The hourly data were aggregated into daily files. This procedure was necessary to develop good correlations between building energy performance and key independent variables such as OAT, space

Table 2

Variables Included in the Data Set

L-Shaped Barracks	
Time of day	Sum of Squares of Electric Data
Date	Sum of Squares of Gas Data
Outdoor Temperature	Btu Heat-3rd Zone
1st Zone East Temperature	Number of Btu Heat-3rd Zone <> 0
1st Zone West Temperature	Sum of Squares of Btu Heat-3rd Zone
2nd Zone East Temperature	
2nd Zone West Temperature	Btu Heat-2nd Zone
3rd Zone East Temperature	Number of Btu Heat-2nd Zone <> 0
3rd Zone West Temperature	Sum of Squares of Btu Heat-2nd Zone
Mess Hall Temperature	
	Btu Heat-1st Zone
Hot Water Supply Temp.-3rd Zone	Number of Btu Heat-1st Zone <> 0
Hot Water Return Temp.-3rd Zone	Sum of Squares of Btu Heat-1st Zone
Hot Water Supply Temp.-2nd Zone	
Hot Water Return Temp.-2nd Zone	Btu Circulating Domestic Hot Water
Hot Water Supply Temp.-1st Zone	Number of Btu Circ. DHW <> 0
Hot Water Return Temp.-1st Zone	Sum of Squares of Btu Circ. DHW
Hot Water Flow-1st Zone	Btu Cooling
Hot Water Flow-2nd Zone	Number of Btu Cooling <> 0
Hot Water Flow-3rd Zone	Sum of Squares of Btu Cooling
Cold Water Feed Temp.	TAll - Average of 7 Space Temps.
Circulating Domestic Hot Water Temp.	TDrm - Average of 6 Space Temps. not including Mess Hall
Cold Water Feed Flow	
Chilled Water Supply Temp.	OAT - Average of Outdoor Temps. as measured at 811, 812, 813
Chilled Water Return Temp.	
Chilled Water Flow	
Electric Use	
Number of Electric Reads	
Gas Use	
Number of Gas Reads	
Scans per Hour	

temperature, and occupancy. If hourly data has been used in the analysis, hourly variations in the data due to equipment cycling, temperature reset schedules, and other short-term building variations would have masked the more important correlations with OAT and interior temperature. During the aggregation process, the data were checked for erroneous or missing data points to ensure that only good data were used for the regression analysis.

Potential dependent and independent variables were selected from the monitored parameter sets for buildings 812 and 813. Regression analyses were performed on the daily data using the SPSS/PC+ Version 2.0 statistical package (Nie et al. 1975). SPSS selected the independent variable set that provided the best fit to the data for the two barracks. Summary statistics were generated for the two buildings and correlation and variance/covariance matrices were developed from the selected set of independent variables.

The regression equations developed for these barracks allowed prediction, with 95 percent confidence limits, of annual gas and heating consumption using bin temperature data. To generate these annual energy predictions, all other variables in the regression equation, except for OAT, were held constant at their average value in the data set. The energy consumption predicted for control/reference building 813 was compared with that of retrofit building 812 to estimate the energy savings due to the EIFS retrofit.

Regression analysis was successful only for the dependent variables of gas and heating energy consumption. No good regression equations could be developed for electricity and cooling energy. T-tests were run on the regression results to determine statistically significant differences in energy consumption between the retrofit and control buildings. A finding of statistically significant differences would support claims that the EIFS retrofit was effective in reducing energy consumption, and that the differences were not due to random variations in energy consumption.

Data Analysis Procedure

Missing and Invalid Data Treatment

The data logger temporarily stopped scanning data channels and collecting data while the memory was being downloaded to USACERL. This downloading procedure typically required less than 5 min and occurred once a week. During the process of aggregating the hourly data files into daily data files, several missing or incorrect data points were identified. The missing data were typically due to data logger downtime, whereas incorrect data points were caused by out-of-calibration sensors or incomplete hours of digital (pulse) data. These incomplete hours occurred when the scanning was stopped for the data logger to download to the USACERL computer via telephone modem. Analog data, such as temperature measurements, were not affected by the scan interruption.

The downloading procedure created an additional problem. When the scanning was stopped and restarted, the minute of the hour at which hourly data were recorded changed after each interruption. This made some days' data less than or greater than 24 actual hours of accumulation, depending on the time of the hour that the scan program was restarted.

Missing and invalid data were replaced with averages of the same parameters for the surrounding hours. Each 24-hr period was assumed to begin at 11 p.m. and was divided into active and inactive periods. The active period lasted 17 hr, beginning at 6 a.m. and ending at 11 p.m. The inactive period lasted 7 hr and ran from 11 p.m. to 6 a.m. Up to 2 hr of missing data in each of these periods were

replaced with the average of the existing data in the active or inactive period. This procedure allowed more than 65 percent of the available data to be used for the regression analysis.

The specific data treatment involved the following:

1. The hourly data were split into pulse accumulation and analog data files since each type of data had to be handled differently.

2. All pulse accumulation records with a total accumulation time not equal to 1 hr were deleted. This step eliminated all accumulated data for the hour after data download to USACERL.

3. Hourly files were recombined.

4. Hourly data were aggregated into active and inactive periods. The accumulated and average analog data were summed for each period.

5. Accumulated sums were prorated within each period according to the available data (e.g., the sum of 5 hr of available data in the inactive period was multiplied by 7/5 to generate the prorated sum for the complete 7-hr period).

6. The analog data were adjusted so that when the values for the two daily periods were averaged, the daily average was correct. (The 7-hr inactive period was multiplied by 7/12 and the 17-hr inactive period by 17/12 before averaging the two values to create the daily average. This step ensured the appropriate weighting of each period based on number of hours in each.)

7. Active and inactive periods were aggregated into 24-hr daily periods starting at 11 p.m. Accumulated data were summed over the day and the weighted average analog data for each period were averaged over the day. This technique ensured that each day consisted of exactly 24 hr of data, irrespective of the actual number of hourly observations or at what point during each hour the observation occurred.

8. A daily average OAT data file was generated. The hourly OAT values from up to three L-shaped barracks were averaged for each hour from whichever values were available. The new average hourly temperatures were averaged into daily values.

9. Daily data for the building files were merged with the daily OAT file to create the final data set used for statistical analysis.

Regression Analysis

Using the treated daily data set for buildings 812 and 813, regressions were performed to identify potential variables that predict the effect of the EIFS retrofit on building 812 energy consumption. Graphical analysis of the data was used in combination with the regression runs to help identify bad data points, seasonal trends, and other significant changes over time.

The regression analysis involved stepwise regressions to identify significant dependent variables and multiple regression using a specific set of variables. Before the regressions were run, the data set was limited to points that met various criteria. The most important criterion was that the dependent variable be nonzero. For heating and gas consumption regressions, the data were included if the daily average OAT was below 65 °F. For cooling consumption, OAT limits above 65, 70, and 75 °F were tried. The multiple temperature limits were used in an attempt to improve the correlation.

The regression and graphical analyses were conducted as follows:

1. Stepwise regressions were run for all relevant dependent variables against all relevant independent variables for buildings 812 and 813 using SPSS/PC+ Version 2.0.

2. The results of the stepwise regression were tabulated for each dependent variable as the next independent variable was included in the regression. This process allowed identification of significant variables and their incremental effect on the predictive power of the regression.

3. If the correlation coefficient for a particular regression run was poor, the results were graphed to determine if bad data or some other effect was preventing the development of a good model.

4. A common set of independent variables was selected for the L-shaped barracks based on the results of the stepwise regression.

5. This common set of variables was used in various combinations to run the multiple regressions.

6. The resulting R-squared value was tabulated for each regression.

7. The combined set of independent variables with the best average R-squared value of the L-shaped barracks was selected to allow common comparison between predictive models for buildings 812 and 813.

8. Regressions were run with the common variable set to generate the predictive regression equations for both barracks. The average values of the independent variables were calculated for the data included in the regression.

9. Bin temperature values from Technical Manual (TM) 5-785 (HQDA, July 1978) and average values of the independent variables from all the L-shaped barracks were used to create a new normalized data set for both barracks buildings. SPSS was used to calculate a predicted value of energy consumption and standard error of estimate for each actual and normalized data point.

10. The standard error, tolerance, correlation coefficient, variance-covariance matrix, and correlation matrix were calculated for the independent variables.

11. The 95 percent confidence limits for the mean at each actual data point were calculated using the standard error and appropriate t-statistic for the actual data set.

12. The results of the predicted versus actual consumption, including confidence limits, were plotted for buildings 812 and 813.

13. The annual predicted energy consumption and uncertainty were calculated for both buildings during the test year.

The results of the regression analysis were predictive models for buildings 812 and 813 that allowed the calculation of predicted annual energy consumption for each building. These energy consumption predictions were used to quantify annual energy savings due to the EIFS retrofit.

Predicting Building Energy Consumption

The regression analysis defined the relationship between energy consumption and the selected independent variables. Using the regression equations, the annual expected energy consumption for buildings 812 and 813 was calculated as outlined in steps 9 and 13 in *Regression Analysis* above.

Weather data from TM 5-785 were used to determine the bin temperature to be input for OAT in the equations. The annual number of hours at each bin temperature for Colorado Springs was used to determine the total annual energy consumption for the buildings. Since other independent variables were included in the regression equations, the annual predictive model had to be normalized for these variables' effect on energy consumption. To accomplish this task, the average value for each variable from all buildings during the heating season was input into the equation. For heating and gas energy consumption, only the average indoor temperature and DHW energy consumption during the heating season were input into the equations.

Once the daily energy consumption for each bin temperature was calculated, that value was divided by 24 hr/day to convert it to an hourly value. These hourly values were then multiplied by the number of hours in the year (in the respective heating or cooling season) that this temperature occurred. The results from each temperature bin were summed to obtain the annual consumption based on average historical weather data.

Since there was a known uncertainty or standard error associated with each coefficient in the regression model, this had to be reflected as error bands or high and low limits around the expected annual energy consumption that had been calculated. These limits were determined by calculating the standard error of the estimate at each bin temperature using the standard error for each coefficient calculated in the regression analysis. The standard error of the estimate was then squared, divided by 24, and multiplied by the number of hours per season in the respective temperature bin. These values were next summed across all temperature bins, the square root of the sum was calculated, and this value was multiplied by the t-statistic (1.96 for an infinite number of cases at the 95 percent confidence level). The resulting value is the uncertainty in the predicted energy consumption for each barracks. The range of predicted annual energy consumption for the buildings was determined by adding and subtracting the uncertainty to the predicted annual energy consumption.

t-Tests

The regression analysis allowed predictive equations to be developed for the gas and heating consumption in buildings 812 and 813. The t-test was then used to show whether the differences in energy consumption, as predicted with the regression equations, were due to actual differences resulting from the EIFS retrofit or if they were simply caused by randomness in the data.

The t-test checks the hypothesis that two data samples are from the same population, i.e., that they are the same, differentiated only by random variations. If the hypothesis is not proven, it can be concluded that the samples are from different populations, and that the differences between them are due to a real, nonrandom, difference.

The t-test requires that the variance of the samples being tested be shown to be homogeneous, with 95 percent confidence. This is done using an Independent-Samples Test, which calculates the F value (a measure of the variances' homogeneity). If there is 95 percent confidence that the variances are homogeneous, then the t-test can be used. If the confidence is less than 95 percent, the t-test is considered invalid.

Results

The dependent and independent variables were selected from those available in the data set (see Table 2). The dependent and independent variables used in the regression analysis are listed in Table 3. The dependent variables include those energy consumptions expected to be identified using the available data sets. The independent variables selected were those which appear to most directly indicate an aspect of building operation known to affect energy consumption. Three independent variables were selected: the average of interior space temperatures, occupancy, and OAT. DHW energy was included in this set since it was expected to be directly related to actual building occupancy.

The incremental effect of each independent variable on the regression models was noted for the barracks. The three variables providing the best fit for all L-shaped barracks were OAT, the average interior temperature (TAll), and DHW consumption (BTUDHW).

Gas consumption and heating Btus were the only two dependent variables that could be predicted accurately using the selected independent variables. None of the other dependent variables provided an adequate fit to develop additional regression models successfully.

The summary statistics on all relevant variables were generated using SPSS and are included in the Appendices A, B, and C for gas consumption, heating energy, and other dependent variables, respectively. The statistics include the mean, standard deviation, minimum, maximum, and number of values for each variable. The correlation and covariance matrices for the variables included in the regression models are also listed in the appendices. The variance-covariance matrix and correlation matrix describe the

Table 3

Dependent and Independent Variables Used in Regression Analysis

Dependent Variables	Independent Variables
Electric Use	Date
Gas Use	1st Floor East Temperature
Btu Cooling	1st Floor West Temperature
Btu Heating	2nd Floor East Temperature
	2nd Floor West Temperature
	3rd Floor East Temperature
	3rd Floor West Temperature
	Mess Hall Temperature
	TAll - Average of 7 Space Temperatures
	TDrm - Average of 6 Space Temperatures not including Mess Hall
	Btu Circulating Domestic Hot Water
	OATAv - Average of Outdoor Temperatures as measured at 811, 812, and 813

relationship between independent variables. These matrices also allow the calculation of confidence intervals for predicted values using the regression equation. The correlation matrix contains the correlation coefficients, which measure the strength of association between variables. The tolerance ($1 - R^2$)of each independent variable is included with other statistics in the appendices. This value provides a measure of the multicollinearity of the independent variables with the other variables in the equation. Multicollinearity occurs when independent variables are linear combinations of one another. In this case, the regression equation is considered invalid. The tolerance for all the variables is greater than 0.01. The equations are valid and therefore meaningful.

The final energy consumption regression equations for buildings 812 and 813 were developed to predict daily gas and heating energy consumption during the 1986/87 and 1987/88 heating seasons. These equations are included in Table 4. Occupancy data served as a poor predictor of energy consumption due to the small amount of variability in the buildings' occupancy during the test period. Figures 5 and 6 depict the relatively level test period occupancy of buildings 812 and 813, respectively. DHW consumption was used as an alternative predictor of occupancy for the regression equations.

The regression equations were used to predict annual energy consumption for the control and retrofit building using the bin temperature data for Colorado Springs, CO. All variables except OAT were held constant to allow comparison of energy consumption between the control and retrofit buildings. For the gas consumption predictions, the average interior temperature and DHW consumption were set at 76.13 °F and 2,078,580 Btu, respectively. For the heating energy consumption prediction, the interior temperature was fixed at the average of the buildings for the test year, 76.36 °F. The DHW consumption was held at 2,291,088 Btu. Table 5 shows the calculations and final results of the heating energy consumption prediction for both barracks. Table 6 shows the same calculations for the gas consumption prediction using the gas consumption regression model and bin temperature data. The tables include an expected energy consumption and a high and low limit. These limits were calculated using the standard errors of each of the independent variable coefficients in the regression equations.

Table 4

Energy Consumption Regression Equations

L-Shaped Barracks - Gas:

812 (87/88): Gas = -107,975,122 - 648,631 *OAT + 2,108,819 *TAll + 0.738 *DHW
812 (86/87): Gas = -92,651,150 - 727,207 *OAT + 1,865,736 *TAll + 4.630 *DHW
813 (87/88): Gas = -63,614,755 - 761,587 *OAT + 1,544,064 *TAll + 3.910 *DHW
813 (86/87): Gas = -62,407,438 - 764,174 *OAT + 1,584,589 *TAll + 1.900 *DHW

L-Shaped Barracks - Heating:

812 (87/88): Heat = -60,735,322 - 445,427 *OAT + 1,159,718 *TAll + 0.515 *DHW
812 (86/87): Heat = -27,302,473 - 408,236 *OAT + 719,930 *TAll + 0.069 *DHW
813 (87/88): Heat = -34,180,655 - 373,474 *OAT + 750,659 *TAll + 1.091 *DHW
813 (86/87): Heat = -20,014,694 - 374,145 *OAT + 591,011 *TAll + 0.143 *DHW

Note: These equations use DAILY values. Gas, Heat, and DHW are the total daily consumption in Btus. OAT and TAll are daily average temperatures (°F).

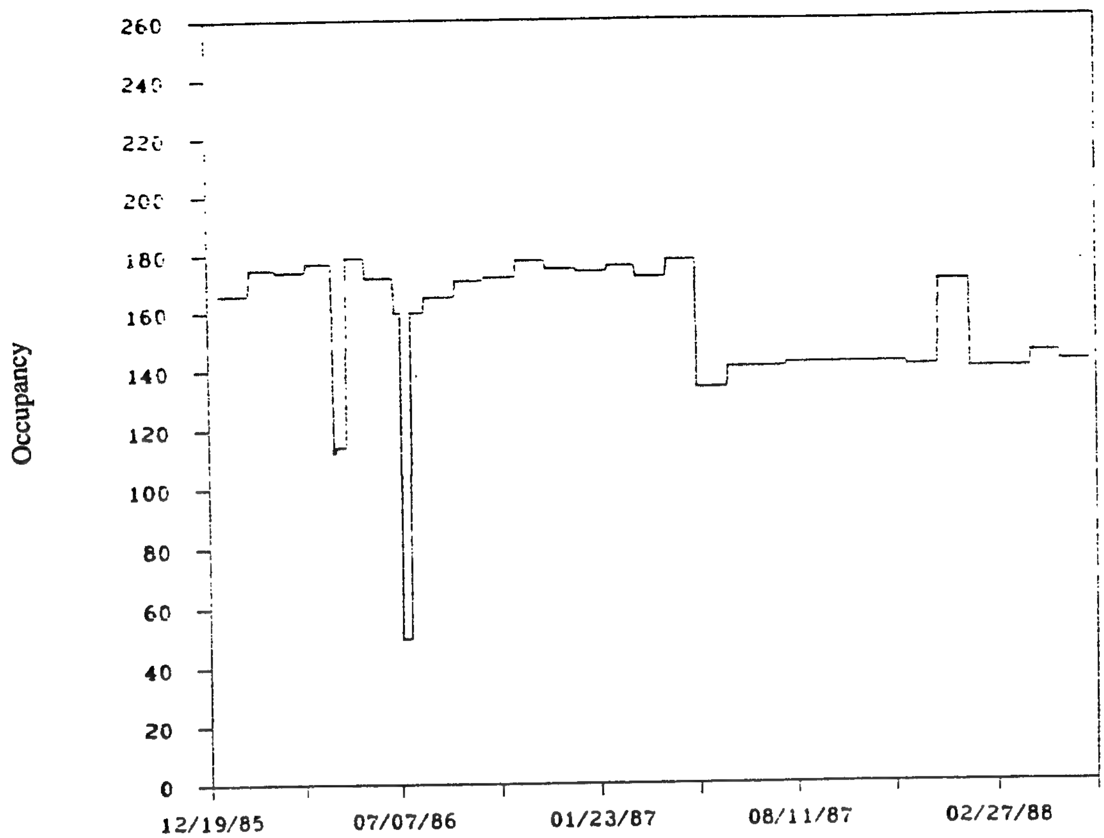


Figure 5. Building 812 Occupancy Data.

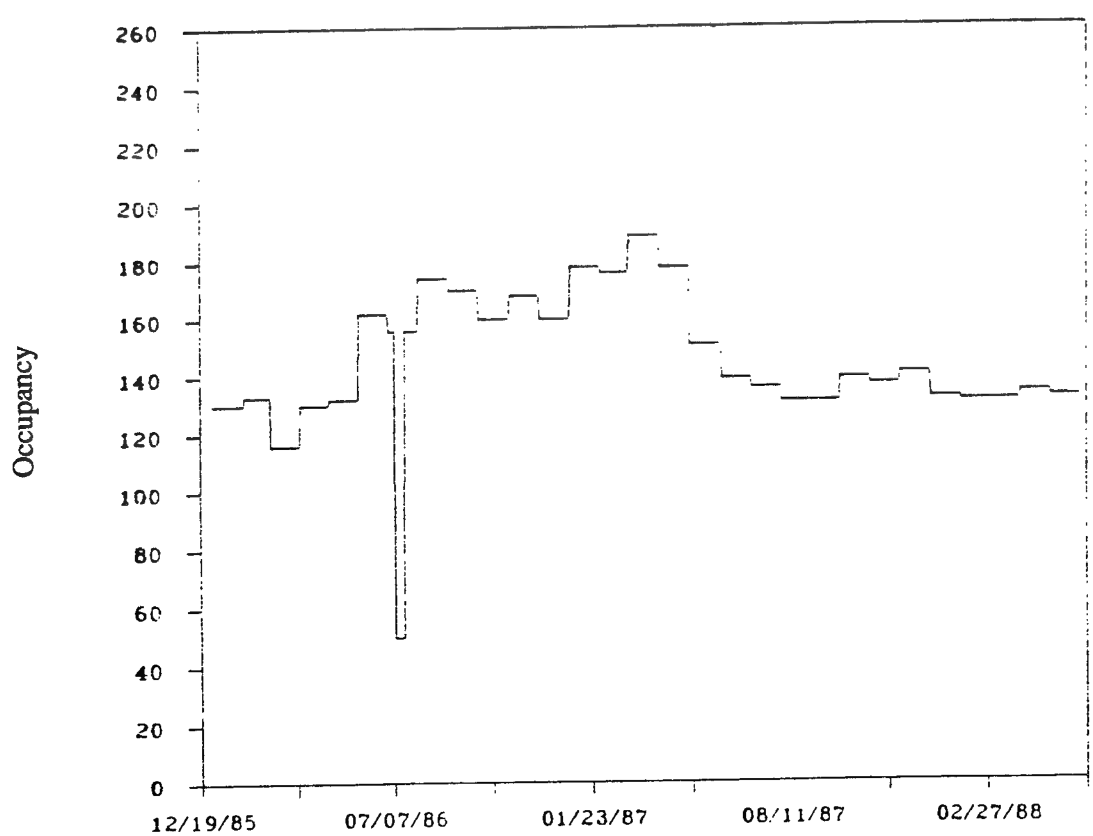


Figure 6. Building 813 Occupancy Data.

Table 5

Annual Heating Consumption Prediction

REGRESSION EQUATION PARAMETERS

Building	Season	Constant	OAT	TAII	BTUDHW	R2
812	1986/87	-27302473	-408236	719930	0.069	0.821
	1987/88	-60735322	-445427	1159718	0.515	0.818
813	1986/87	-20014694	-374145	591011	0.143	0.787
	1987/88	-34180655	-373474	750659	1.019	0.833

Bin Temp	Oct Thru May Hrs	Hourly Heat at Bin T [KBtu] 1986/87 812	Hourly Heat at Bin T [KBtu] 1986/87 813	Hourly Heat at Bin T [KBtu] 1987/88 812	Hourly Heat at Bin T [KBtu] 1987/88 813	Annual Heat at Bin T [MBtu] 1986/87 812	Annual Heat at Bin T [MBtu] 1986/87 813	Annual Heat at Bin T [MBtu] 1987/88 812	Annual Heat at Bin T [MBtu] 1987/88 813
62	299	108.77	96.61	63.39	99.56	33	29	19	30
57	394	193.82	174.55	156.18	177.37	76	69	62	70
52	527	278.87	252.50	248.98	255.17	147	133	131	134
47	627	363.92	330.45	341.78	332.98	228	207	214	209
42	668	448.97	408.39	434.58	410.79	300	273	290	274
37	657	534.02	486.34	527.37	488.60	351	320	346	321
32	672	619.07	564.29	620.17	566.40	416	379	417	381
27	582	704.12	642.24	712.97	644.21	410	374	415	375
22	438	789.17	720.18	805.77	722.02	346	315	353	316
17	242	874.22	798.13	898.56	799.82	212	193	217	194
12	137	959.27	876.08	991.36	877.63	131	120	136	120
7	80	1044.32	954.02	1084.16	955.44	84	76	87	76
2	46	1129.36	1031.97	1176.95	1033.25	52	47	54	48
-3	20	1214.41	1109.92	1269.75	1111.05	24	22	25	22
-8	11	1299.46	1187.86	1362.55	1188.86	14	13	15	13
-13	3	1384.51	1265.81	1455.35	1266.67	4	4	4	4
-18	2	1469.56	1343.76	1548.14	1344.47	3	3	3	3
-23	0	1554.61	1421.70	1640.94	1422.28	0	0	0	0
					Expected:	2830	2577	2789	2590
					High:			2792	2592
					Low:			2786	2588
					Std Error:			3.09	2.24

The expected annual gas savings for building 812 due to the EIFS retrofit should be 11.1 percent based on Table 6 compared with building 813's predicted consumption. However, the expected heating energy savings from the regression equations is -7.1 percent, ± 0.2 percent for retrofit building 812 versus the control building. At first, this negative savings is alarming to see as a result, since it might suggest that the energy conservation retrofit is actually causing the building the consume more energy than it did before. This is not the case, however. Based on the regression equations for the 1986/87 heating season, building 812 consumed more heating energy than building 813 before the EIFS installation. The actual daily heating and gas consumption during the preretrofit (1986/87) heating season support this pattern (see statistical summaries of daily data in Appendices A and B). Building 812 was predicted to consume 2830 MBtu, or nearly 9 percent more heating energy than building 813. Building 813's predicted consumption was only 2577 MBtu in heating energy under identical operating conditions. This comparison suggests that building 812 has operating characteristics that cause it to consume more heating energy than building 813 to provide the same level of occupant comfort. Since building 812 consumes only 7.1 percent more energy than building 813 after the retrofit, the EIFS has resulted in a net decrease in the predicted gas energy required to maintain building conditions compared with the preretrofit energy consumption model. In addition, the actual daily values of heating and gas consumption for building 812 decreased from 1986/87 to 1987/88. This reduction was not due to a milder heating season since there were 6096 HDD in 87/88 versus 5968 HDD in 86/87. This overall energy decrease may have been the result of more careful building operation and faster response to equipment failure since the buildings were being monitored.

The results of the predicted versus actual consumption, including confidence limits, were plotted for buildings 812 and 813 (Figures 7 and 8, respectively, for gas and Figures 9 and 10, respectively, for heating energy). These plots are an indication of the models' predictive power. They indicate that the regression model for building 812 is not as strong during low daily energy consumption periods (e.g., the swing seasons in the spring and fall); however, it is a good model for the higher daily heating consumption periods. The models for building 813 match well with the actual data throughout the range.

Figures 11 and 12 are frequency distribution plots of the number of days included in the final data sets, by month of the test period, for buildings 812 and 813, respectively. These plots were generated to show that the data manipulations did not result in excessive chronological skewing of the data sets.

The regression models and resulting energy consumption predictions suggest that the EIFS retrofit makes building 812 consume more heating energy than building 813 but less gas. However, the significance of these differences must be checked. The differences could simply be due to randomness of the data sets or other effects that would not make the comparison valid. To assess this possibility, t-tests were performed on all independent variables. Tables 7 through 10 show the results. For all dependent variables except for heating energy, the tests showed that there were no statistically supportable differences in energy consumption as predicted by the regression equations for the L-shaped barracks. For the 1987/88 test year, the t-test suggests that differences in the predicted heating energy consumption of buildings 812 and 813 are statistically supportable. It is unlikely that the EIFS retrofit would have resulted in an increased heating load. In fact, Table 5 shows that there is a reduction in building 812 annual heating requirements between 1986/87 and 1987/88 under identical operating conditions. The table also shows that building 812 heating requirements were higher than building 813 prior to the retrofit.

Since the t-test failed, the predicted differences between the retrofit and nonretrofit buildings were due to randomness in the data. Based on these results, the regression models could not be used to accurately predict the energy savings potential of the EIFS retrofit on L-shaped barracks.

Many operational characteristics of the buildings created additional problems for measuring the potential savings with the EIFS system. Among these problems, the most important may have been the

Table 6

Annual Gas Consumption Prediction

REGRESSION EQUATION PARAMETERS

Building	Season	Constant	OAT	TAll	BTUDHW	R2
812	1986/87	-92651150	-727207	1865736	4.63	0.799
	1987/88	-107975122	-648631	2108819	0.738	0.89
813	1986/87	-62407438	-764174	1584589	1.9	0.784
	1987/88	-63614755	-761587	1544064	3.91	0.904

		Hourly Gas at Bin T (KBtuH)				Annual Gas (MBtu)			
		1986/87		1987/88		1986/87		1987/88	
Bin Temp	Oct Thru May Hrs	812	813	812	813	812	813	812	813
62	299	579.87	616.31	578.32	618.23	173	184	173	185
57	394	731.37	775.52	713.45	776.89	288	306	281	306
52	527	882.87	934.72	848.58	935.56	465	493	447	493
47	627	1034.37	1093.92	983.72	1094.22	649	686	617	686
42	668	1185.88	1253.12	1118.85	1252.89	792	837	747	837
37	657	1337.38	1412.33	1253.98	1411.55	879	928	824	927
32	672	1488.88	1571.53	1389.11	1570.21	1001	1056	933	1055
27	582	1640.38	1730.73	1524.24	1728.88	955	1007	887	1006
22	438	1791.88	1889.94	1659.37	1887.54	785	828	727	827
17	242	1943.38	2049.14	1794.50	2046.21	470	496	434	495
12	137	2094.88	2208.34	1929.64	2204.87	287	303	264	302
7	80	2246.39	2367.54	2064.77	2363.53	180	189	165	189
2	46	2397.89	2526.75	2199.90	2522.20	110	116	101	116
-3	20	2549.39	2685.95	2335.03	2680.86	51	54	47	54
-8	11	2700.89	2845.15	2470.16	2839.53	30	31	27	31
-13	3	2852.39	3004.36	2605.29	2998.19	9	9	8	9
-18	2	3003.89	3163.56	2740.42	3156.85	6	6	5	6
-23	0	3155.39	3322.76	2875.56	3315.52	0	0	0	0
					Expected	7129	7529	6689	7525
					High:			6692	7528
					Low:			6686	7522
					Std. Error:			3.05	3.44

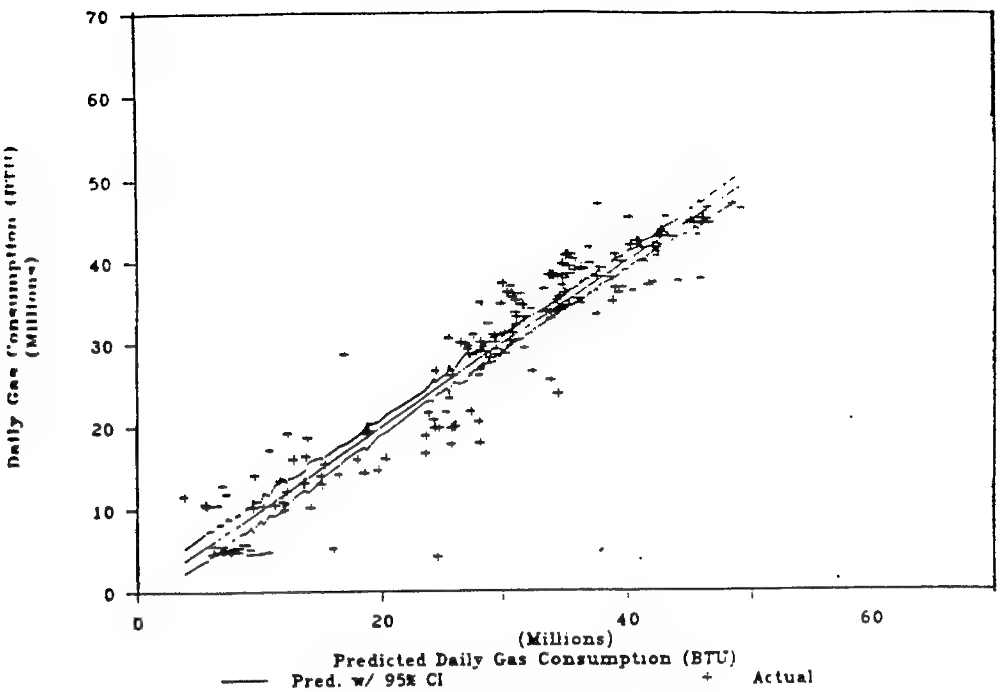


Figure 7. Actual vs. Predicted Gas Consumption: Building 812.

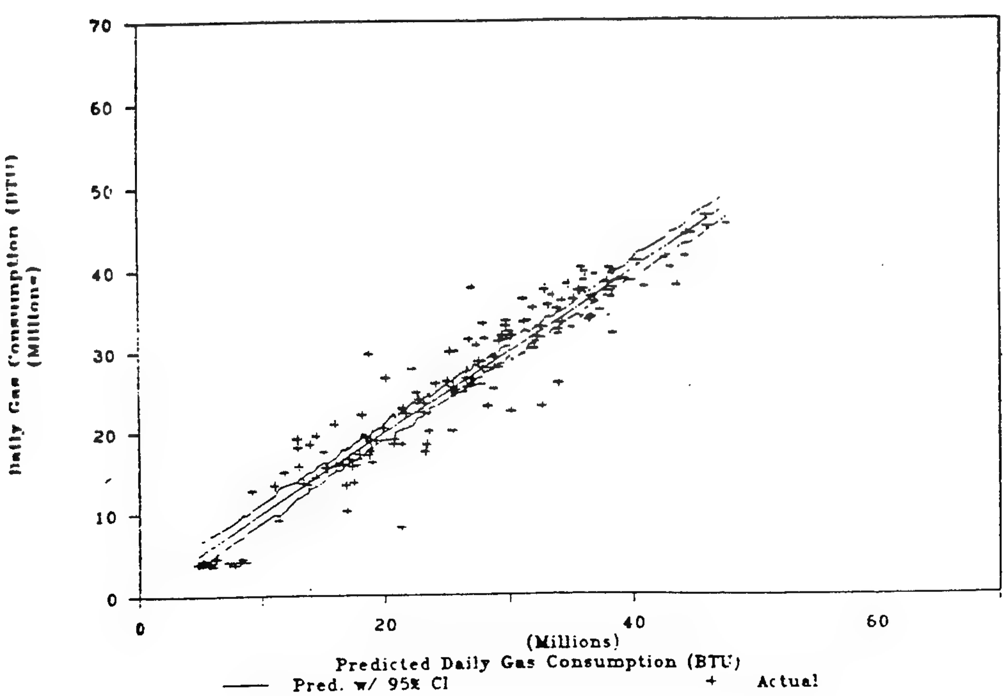


Figure 8. Actual vs. Predicted Gas Consumption: Building 813.

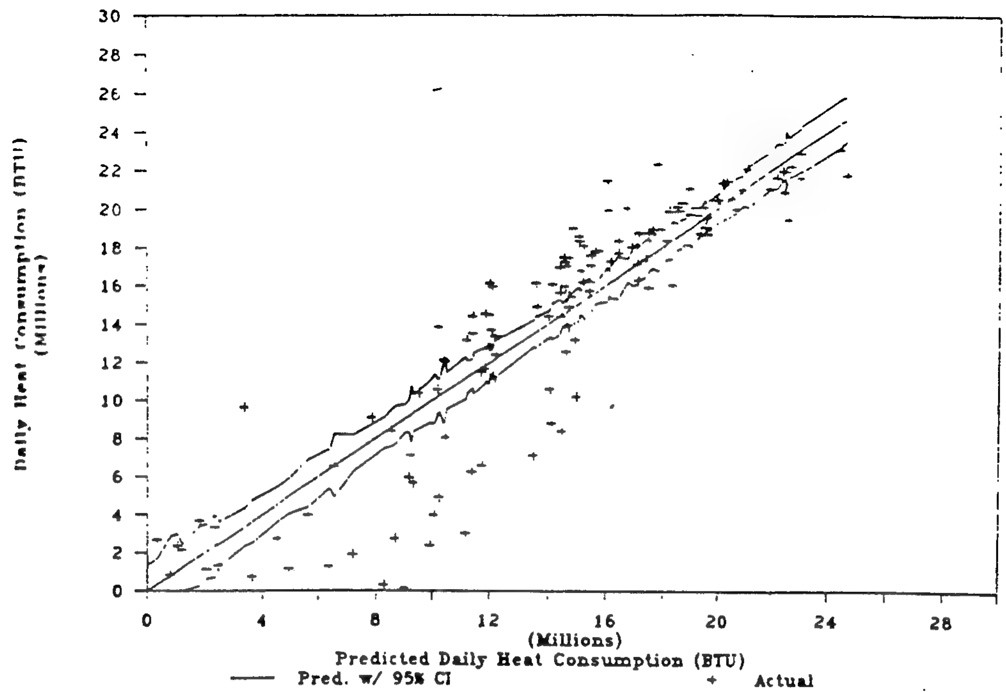


Figure 9. Actual vs. Predicted Heating Use: Building 812.

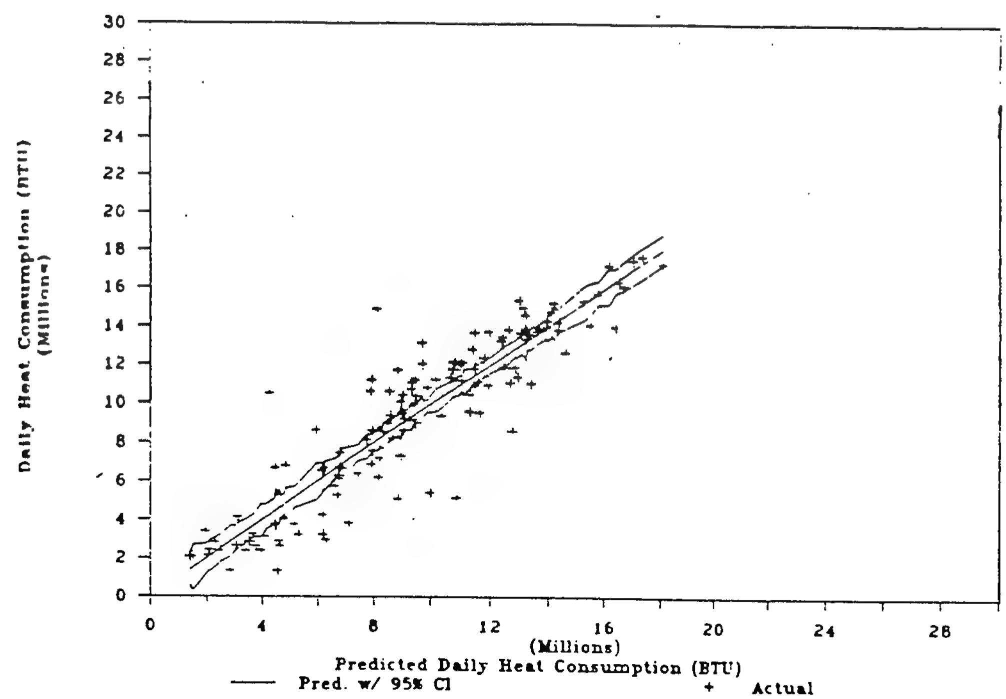


Figure 10. Actual vs. Predicted Heating Use: Building 813.

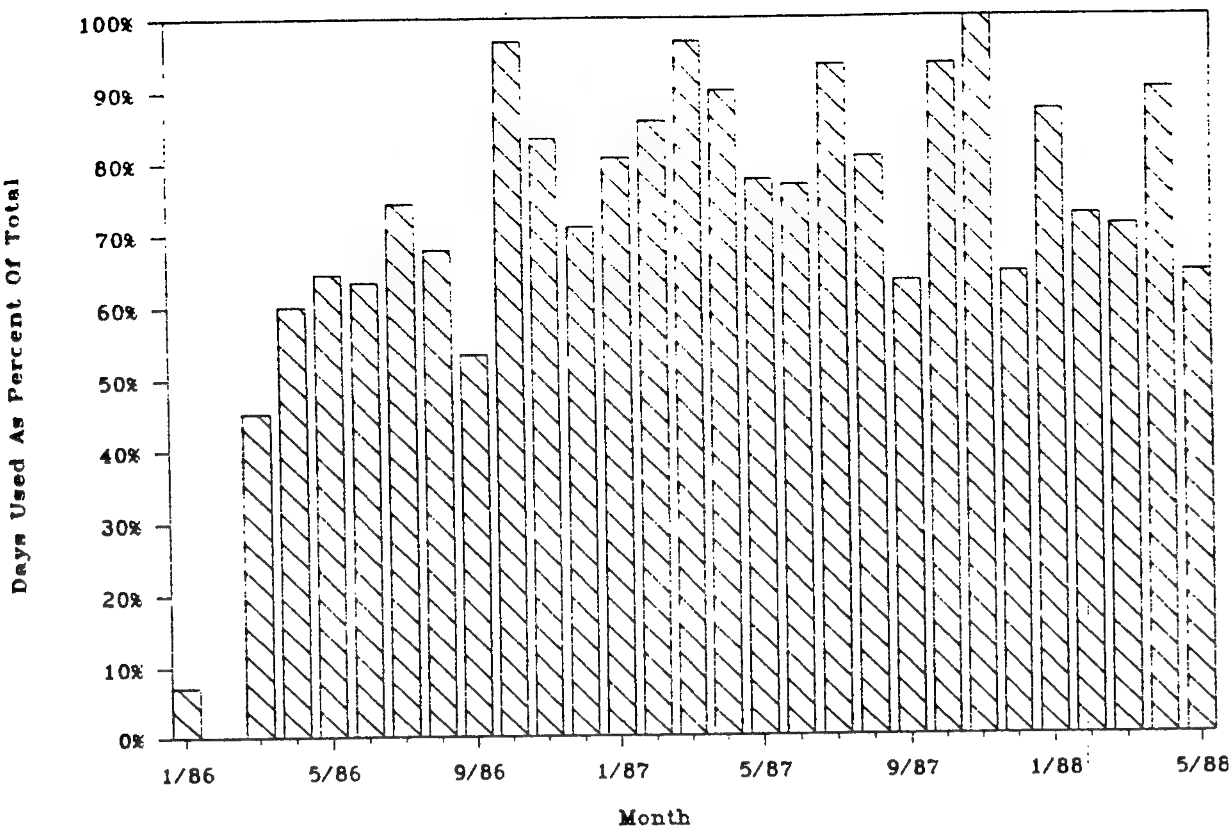


Figure 11. Data Days Used: Building 812.

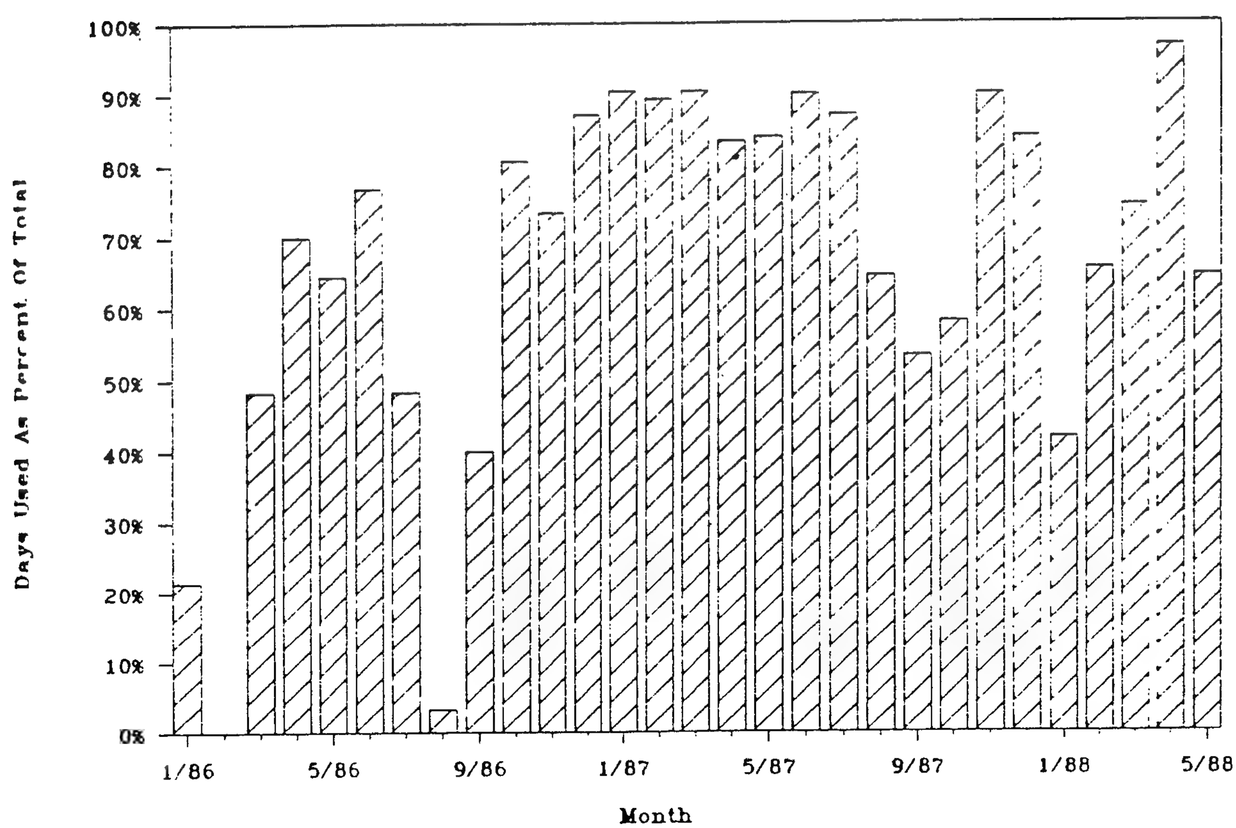


Figure 12. Data Days Used: Building 813.

Table 7

t-Test of Independent Variables: Gas*

Building (Year)	F Value	2-Tail Prob.	t Value	2-Tail Prob.
812 (86/87) vs. 812 (87/88)	1.20	0.173	0.35	0.725
812 (86/87) vs. 813 (86/87)	1.55	0		
812 (86/87) vs. 813 (87/88)	1.52	0.003		
812 (87/88) vs. 813 (86/87)	1.29	0.051	1.04	0.299
812 (87/88) vs. 813 (87/88)	1.27	0.121	1.51	0.132
813 (86/87) vs. 813 (87/88)	1.02	0.878	0.68	0.498

*86/87 includes up to August 31, 1987; 87/88 includes September 1, 1987 and later. Date included if gas > 50,000 Btu and daily average outdoor air temperature ≤ 65 °F.

inability of the installed control system to provide adequate comfort to the occupants. The building 812 average interior temperature was greater than 77 °F during the 1987/88 heating season. On several occasions, the interior temperature in some zones exceeded 90 °F. These high temperatures resulted in barracks windows being wide open all day in an attempt to maintain comfort. The open windows resulted in higher building envelope thermal losses than would be expected of a properly controlled building with

Table 8

t-Test of Independent Variables: Heating and Cooling

Building (Year)	F Value	2-Tail Prob.	t Value	2-Tail Prob.
Heating*				
812 (86/87) vs. 812 (87/88)	1.89	0		
812 (86/87) vs. 813 (86/87)	1.71	0		
812 (86/87) vs. 813 (87/88)	2.44	0		
812 (87/88) vs. 813 (86/87)	3.24	0		
812 (87/88) vs. 813 (87/88)	1.29	0.136		
813 (86/87) vs. 813 (87/88)	4.19	0	2.66	0.008
Cooling**				
812 vs. 813	3.89	0		

*86/87 includes up to August 31, 1987; 87/88 includes September 1, 1987 and later. Date included if heating > 50,000 Btu, daily average outdoor air temperature ≤ 65 °F, and date after 8/25/86.
**Based on data for 1986 and 1987 cooling seasons, up to September 1, 1987. Data included if cooling > 50,000 Btu..

Table 9

t-Test of Independent Variables: Electricity*

Building (Year)	F Value	2-Tail Prob.	t Value	2-Tail Prob.
812 (86/87) vs. 812 (87/88)	1.07	0.605	4.49	0
812 (86/87) vs. 813 (86/87)	2.06	0		
812 (86/87) vs. 813 (87/88)	2.57	0		
812 (87/88) vs. 813 (86/87)	1.93	0		
812 (87/88) vs. 813 (87/88)	2.42	0		
813 (86/87) vs. 813 (87/88)	1.25	0.082	3.22	0.001

*86/87 includes up to August 31, 1987; 87/88 includes September 1, 1987 and later. Date included if electricity > 0 kWh, gas > 50,000 Btu, and daily average outdoor air temperature ≤ 65 °F.

all windows closed during the cold winter. The EIFS retrofit to building 812 appeared to result in an increased frequency and percentage of open windows compared with the control building.

No fresh air was provided to the building occupants through the HVAC system. The baseboard hot water heating system provided no outside air and the fresh air intake had been blocked off for the main air handling units. This lack of fresh air resulted in more open windows in an attempt to improve the

Table 10

t-Test of Independent Variables: Electricity During the Heating and Cooling Seasons

Building (Year)	F Value	2-Tail Prob.	t Value	2-Tail Prob.
Heating*				
812 (86/87) vs. 812 (87/88)	1.60	0		
812 (86/87) vs. 813 (86/87)	2.37	0		
812 (86/87) vs. 813 (87/88)	1.56	0.001		
812 (87/88) vs. 813 (86/87)	3.80	0		
812 (87/88) vs. 813 (87/88)	2.50	0		
813 (86/87) vs. 813 (87/88)	1.52	0.001		
Cooling**				
812 vs. 813	2.81	0		

*86/87 includes up to August 31, 1987; 87/88 includes September 1, 1987 and later. Date included if electricity > 0 kWh, gas > 50,000 Btu, and daily average outdoor air temperature ≤ 65 °F.
**Based on data for 1986 and 1987 cooling seasons, up to September 1, 1987. Data included if electricty > 0 kWh and cooling > 50,000 Btu..

general air quality and to lessen the high odor levels prevalent in some areas of the barracks. The bathrooms contained laundry facilities, lavatories, wash basins, showers, and toilets. No exhaust fan system existed to reduce the high humidity and odors that routinely occurred in these areas. Consequently, many bathroom windows were left open during the day, further compromising the building envelope thermal integrity and adding to the poor predicted energy performance of the EIFS retrofit.

The control system design and operation created additional problems in maintaining adequate occupant comfort during the heating season. Three separate control systems supplied hot water to the baseboard heaters in the three building zones. These controls were designed to maintain a fixed temperature hot water supply to the building as long as the OAT was below a certain temperature (typically 55 °F). If the OAT was above this setpoint, the zone supply water pumps were shut off. The controllers sensed the zone heating return water temperature and adjusted the steam supplied to the steam-to-hot water converter to maintain the desired supply temperature. Since there is no feedback from the occupied spaces to reset the supply water temperature based on actual heating requirements, this control strategy led to significant overheating of the building.

The controller feedback was the return water temperature. This resulted in very high potential setpoint temperature overshoot since an increase in water temperature, created at the converter, had to travel through the entire zone plumbing loop before it was sensed and the steam valve adjusted accordingly.

Additional problems resulted from the controllers and steam valves failing to provide the desired setpoint temperature to the zone. During weeks 10 and 11 of 1988, the buildings were carefully monitored day and night in an attempt to prevent building overheating and reduce the occurrence of window openings. When the zone 1 and 2 (west and east three-story barracks sections, respectively) heating supply water temperature controllers were set at their minimum level of 70 °F, the zones continued to be supplied with 120 and 140 °F hot water for baseboard heating. This condition was occurring when OATs were ranging from a low of 45 to a high of nearly 80 °F. The pumps had to be shut off manually to ensure that no hot water was delivered to the zones during these high OAT periods. The boiler continued to run and maintain minimum steam pressure. There were no controls that shut off the boiler during the heating season if the OAT exceeded a particular setpoint.

The original building design was for open-bay barracks and, therefore, the hydronic heating system consisted of hot-water baseboard heaters that ran through 8 to 15 rooms on each floor before coming back to the main hot-water return header in the crawlspace. The hot water supply line ran up from the crawlspace and had parallel plumbing for floors 1, 2, and 3. If any air was in the system, it tended to rise to the top of the riser on the third floor. Since there were no automatic air bleeds at the top of each heating water supply riser, air would collect in the third-floor plumbing loop and prevent adequate hot water supply to the rooms served by that loop. This condition routinely triggered telephone calls to the installation Directorate of Engineering and Housing (DEH) to provide more heat. The heating supply water temperature was often set higher in the mechanical room without investigating the cause for the lack of heat on the third floor. The result of this action was that the third floor rooms with air entrained in the hydronic heating loop continued to be underheated and the rest of the building became overheated.

Although building occupants had no means of controlling the hot water temperature supplied to their rooms, the baseboard heaters had covers installed over the finned convective surfaces. These covers included a hinged door that could be used to control the amount of air allowed to pass across the baseboard heaters. The doors were not operable during the experimental period because all of the pull chains had been broken or removed. However, the doors could be made functional again by lubricating the hinges and installing new pull chains.

The design of the HVAC system and its controls made proper building temperature control and maintenance of adequate occupant comfort nearly impossible during the test period. This resulted in many troops routinely opening their windows in an attempt to provide the minimum fresh air for odor control and cool air to reduce the severity of overheating in most of the building.

Direct Comparison Energy Data

Poor mechanical system operations lead to significantly reduced building efficiency and overheating of occupied spaces during the test year heating season, as noted in the previous section. These conditions may have masked energy efficiency improvements due to the EIFS retrofit. The buildings needed to be maintained at reasonably comfortable interior temperatures to reduce window openings. The mechanical systems required continual manual adjustment and maintenance to provide appropriate heating based on weather conditions.

The energy data collected during most of the 1987/88 heating season indicated no significant energy savings due to the EIFS retrofit. An intensive test period with improved building operations was initiated to try and identify EIFS-related energy savings for the buildings when proper mechanical system operation and reasonable comfort conditions were maintained. Appendix D contains the data collected during this period.

During weeks 10 and 11 of 1988 (March 12 through 25), buildings 812 and 813 were monitored and maintained around the clock. The controls were adjusted continually in an effort to reduce the overheating of the barracks. Air was bled from the hydronic heating system to ensure that all floors were receiving adequate heat. The barracks were routinely inspected for open windows and windows were closed as soon as they were discovered. Any mechanical system failures were reported immediately to the DEH and typically repaired within a few hours.

The 2-week improved operations resulted in average interior temperatures of 73 °F in building 812 and 74 °F in building 813 (Table 11). These conditions are a significant improvement from the average interior temperature occurring during the rest of the heating season. Building 812 averaged 78 °F and building 813 averaged 75 °F during the peak heating season beginning 31 October 1987 and ending 11 March 1988. The fact that building 812 was maintaining an interior temperature 3 °F warmer than building 813 may have been a major contributor to the small gas and heating energy savings recorded for most of the 1987/88 heating season. This higher interior temperature in building 812 also resulted in more windows being opened. These open windows reduced the overall thermal efficiency of the building envelope.

Table 11

Hot Water Supply Temperature by Week and Building

Bldg	Week	HWS Zone 3	HWS Zone 2	HWS Zone 1	Inside Temp
812	8743-8809	143	173	193	78
	8810	138	160	143	74
	8811	95	140	120	72
813	8743-8809	196	153	171	75
	8810	197	154	179	74
	8811	204	118	120	74

Figure 13 is a plot of the average daily interior temperatures for buildings 812 and 813 during weeks 10 and 11. Average daily OAT is also plotted to show that, during most of this 2-week test period, the zone hot water heating pumps were running to supply fixed-temperature hot water to the occupied spaces. Although the interior temperatures were maintained between 72 and 75 °F for both buildings, conditions were still uncomfortable for occupants and window opening continued to occur. Heating supply water temperatures were routinely reduced during the 2 weeks to lower the space temperature further. Figure 13 shows that no significant change was made to interior temperatures once the level was reduced from its higher seasonal averages reported in Table 11.

Figure 14 shows the average interior temperatures of zones 1 (west), 2 (east), and 3 (south) in building 812 during weeks 10 and 11. Figure 15 depicts the same data points for control/reference building 813 over the same period. Based on the plots, only the south zone appears to increase in temperature as OATs rise. This situation is not representative of operation during most of the heating season. The temperatures in zones 1 and 2 of the three-story barracks were kept from rising with the increased OAT by manual adjustment of the supply water temperature controllers and the supply water pumps. Since the control loops had no zone temperature feedback, these types of control actions, based on plots like Figure 14 and 15, were used to adjust the temperature controllers for heating supply water during the 2-week intensive building monitoring period.

As noted earlier, the buildings were still overheated. The major reason for this condition was the failure of the zone supply water temperature control systems to properly control the steam delivered to the converters and maintain the desired supply water temperature.

Building 812 controls for zones 1 and 2 were set to 80 °F during week 10 and to their minimum setting of 70 °F during week 11 of 1988. Despite these control settings, Table 11 indicates that zone 1 supply water temperature was 143 °F during week 10 and 120 °F during week 11. Zone 2 water

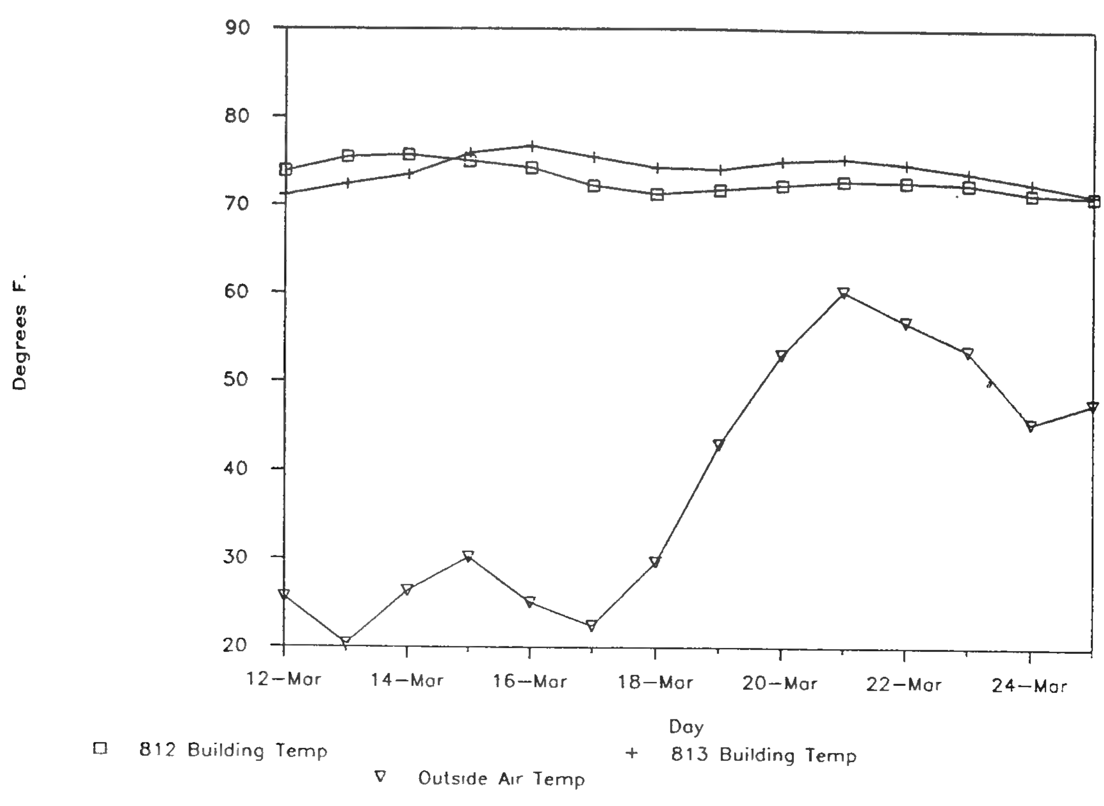


Figure 13. Building Temperature Profiles, Weeks 10 and 11, 1988.

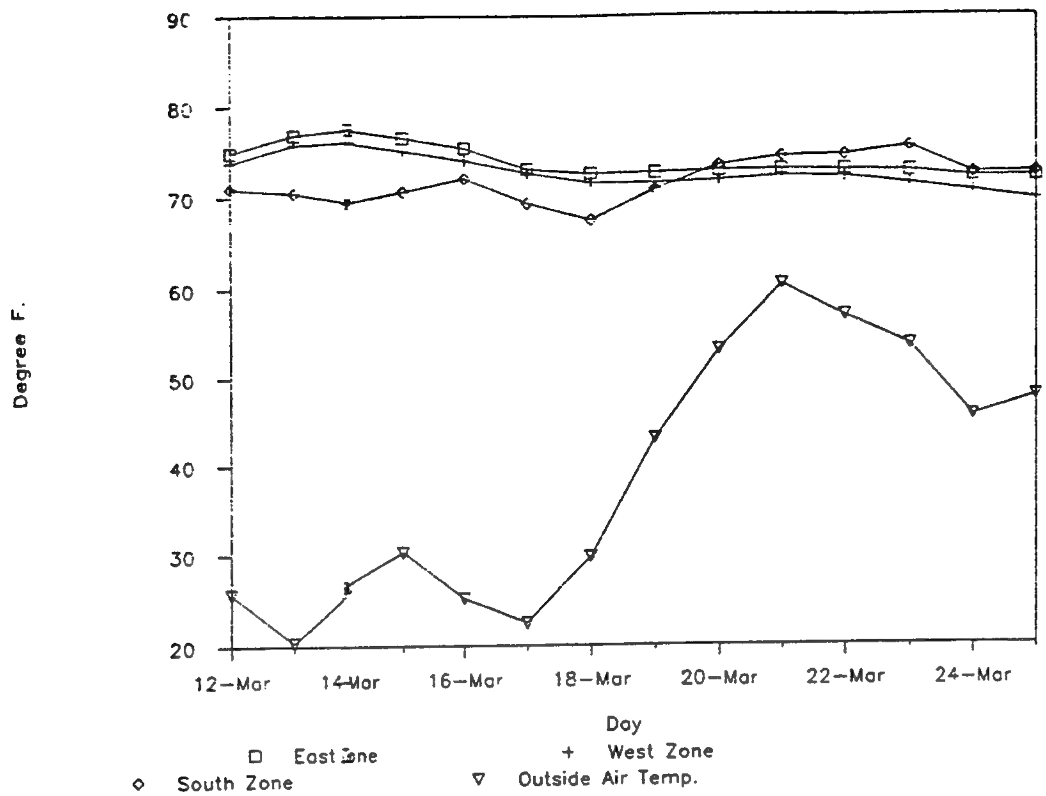


Figure 14. Interior Temperature Profiles, Weeks 10 and 11, 1988: Building 812.

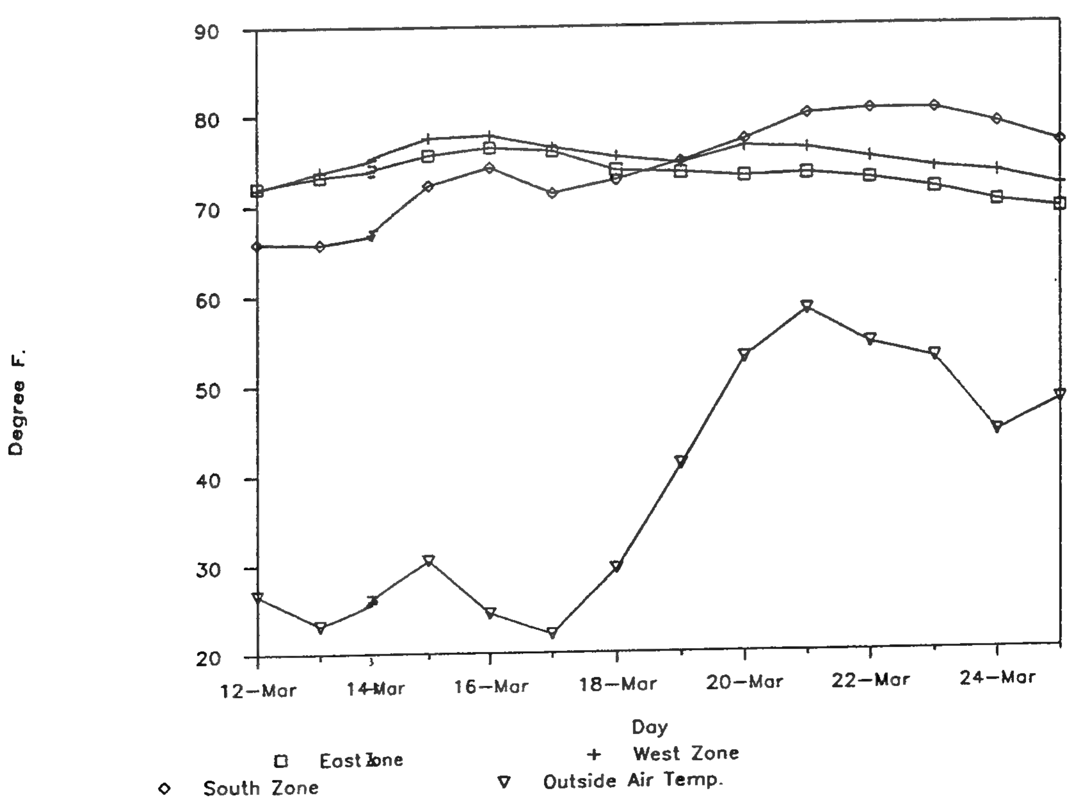


Figure 15. Interior Temperature Profiles, Weeks 10 and 11, 1988, Building 813.

temperatures averaged 160 and 140 °F during weeks 10 and 11, respectively. Building 813 supply water temperatures averaged well above 120 °F for both zones.

Figures 16 and 17 are plots of the average daily supply water temperatures for buildings 812 and 813 for zones 1 and 2, respectively, during weeks 10 and 11. These figures indicate that the supply water temperature was reduced as a result of the control adjustments. However, the delivered water temperature was much higher than the respective control settings. This inability to throttle the steam flow to the converters and reduce the supply water temperature adequately contributed to the overheating of occupied spaces. The problem may have been the result of failing steam valves, oversized steam valves that could not throttle the steam in proportion to the required controller setting, or inappropriate or uncalibrated control components. Overall, the control system was inadequate for the desired control actions.

Zone 3 supply water temperatures were even more poorly controlled than zones 1 and 2. Figure 18 is a plot of zone 3 supply water temperatures for both buildings. Building 813 temperature remained above 200 °F except during part of week 10. The week 10 average was lower due to pump downtime required to replace a failing pump. No control setting would reduce the supply water temperature below 200 °F during the test period. Table 11 shows that, in building 813, zone 3 supply water temperature averaged 196 °F throughout the entire heating season. The low average building 812 supply water temperature in zone 3 during week 11 was the result of the zone 3 pump being off due to high OAT on March 21 through 23.

Zone 3 contained the only control loop that had occupied space temperature feedback to the heating loop. This south zone had an adjustable thermostat in a conference room of both buildings. The occupants could adjust the controller to provide heating hot water to perimeter radiators based on the thermostat setting. However, building occupants were not aware that they had some control over interior temperatures in zone 3. The thermostats were typically set as high as possible. This action resulted in

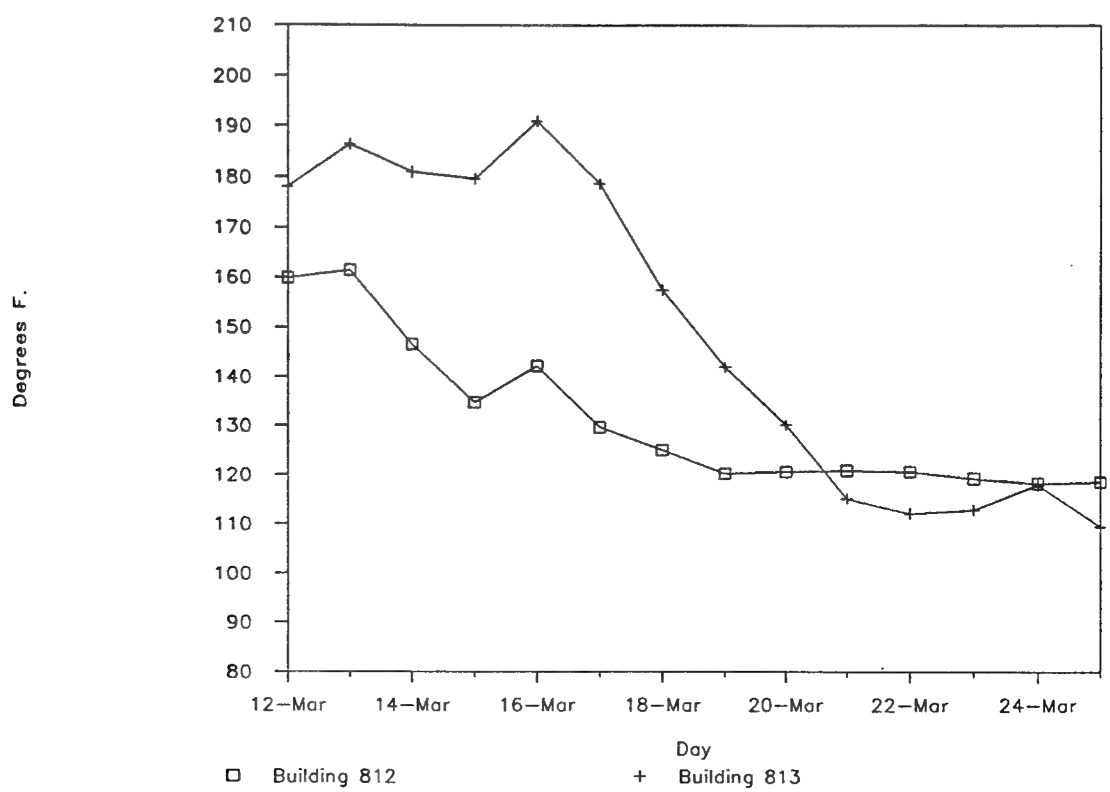


Figure 16. Hot Water Supply Temperature: Zone 1.

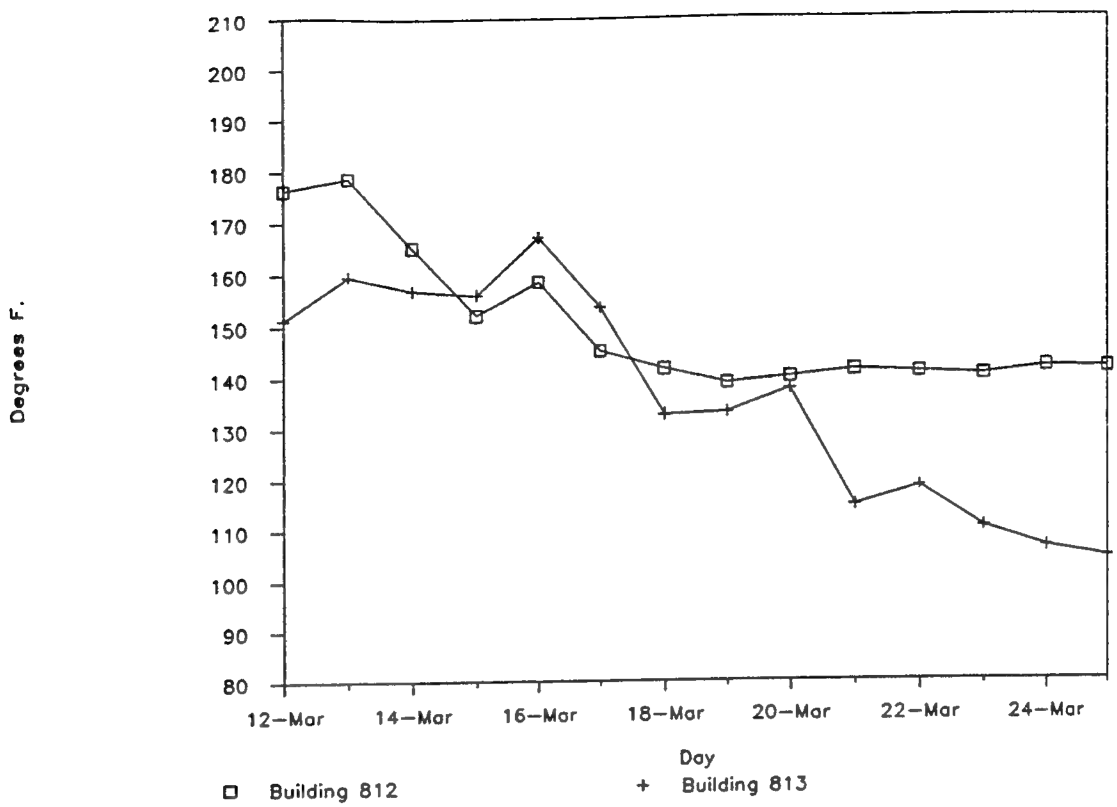


Figure 17. Hot Water Supply Temperature: Zone 2.

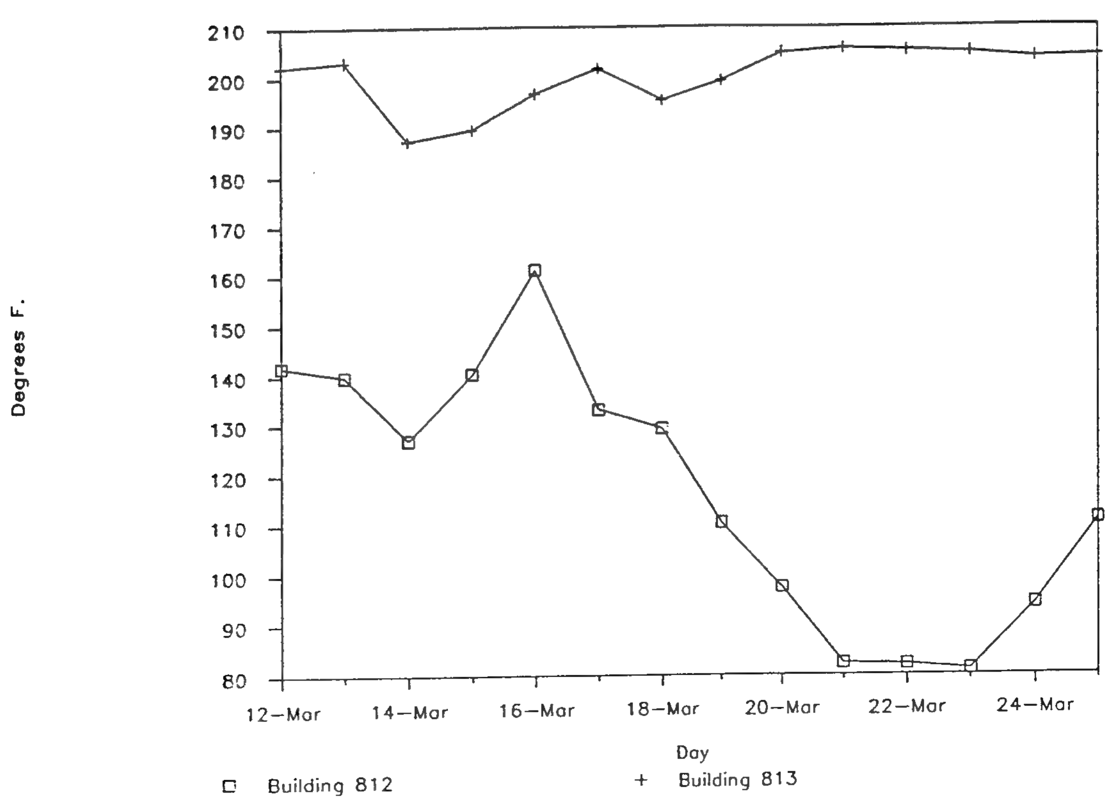


Figure 18. Hot Water Supply Temperature: Zone 3.

extreme overheating of this space in building 813 during week 11 when OATs were relatively warm. Figure 15 shows the overheating that occurred in zone 3 during week 11. Since the zone 3 steam valve and supply water pump were shut off in building 812 during most of week 11, the overheating was not as severe as in building 813.

Table 12 shows the results of the direct comparison of site energy consumption for buildings 812 and 813. Based on this data, building 812 had an overall heating system efficiency of 49.7 percent while the efficiency of building 813 was 45.9 percent. This heating efficiency includes both zone heating and DHW heating energy, but does not account for heating energy provided to unmetered gas dryers. Since building 812 was converting gas to heating Btus more efficiently than building 813, the gas savings for building 812 versus 813 were greater (7.6 percent) than the percentage savings of heating Btus (1.8 percent) during most of the 1987/88 heating season. Since the gas dryers are not metered for gas consumption, it may be more appropriate to compare the heating energy consumed by the two buildings (in Btu) to develop an accurate picture of the energy consumption patterns attributable to the EIFS retrofit.

Zone 1 in building 812 indicates positive energy savings when compared with zone 1 in building 813 during the 2-week test period (Table 12). Part of this savings is due to the higher supply water temperature in building 813 during week 10 indicated in Table 11. However, energy savings of 84.9 percent were observed during week 11 when the zone 1 supply water temperatures were nearly identical at an average of 120 °F for the week (see Figure 16 and Table 11). This heating energy savings, with both buildings' zones operating under identical conditions and at identical supply water temperatures, suggest that the thermal efficiency of the EIFS retrofit may have been a significant contributor to the heating energy savings achieved during this brief test period.

Table 12 indicates that zone 2 in building 812 consumed 88 percent more heating energy than zone 2 in building 813 during week 43 of 1987 through week 9 of 1988 during the heating season. This excessive energy consumption was the result of the poor hot water supply temperature control discussed previously. Table 11 supports this claim. The zone 2 supply water temperature averaged 173 °F in building 812 compared with 153 °F for zone 2, building 813, during the same period. During weeks 10 and 11, this poor control continued to cause zone 2 of building 812 to consume an average of 43 percent more heating energy than zone 2 in building 813. Figure 17 is a graph of the average hot water supply temperature of zone 2 in both buildings during the 2-week period beginning March 12, 1988. Table 11 shows the average of the supply water temperatures for each of the zones over the 2 weeks. Zone 2 of building 812 maintained a 2-week average supply water temperature of 150°F. This was consistently warmer than the 2-week average of 136 °F for zone 2 in building 813 and contributed to the higher zone 2 energy consumption in building 812.

Since zone 3 supply water temperatures were poorly controlled, it is not possible to reach conclusions on the relative impact of the EIFS retrofit on heating energy consumption in this 6878 sq ft space of the L-shaped barracks. This zone had a controller that was designed to sense the space temperature and provide appropriate heating. However, the controller was randomly set to various temperatures by occupants. The occupants were unaware that it was a functioning thermostat that could provide them with an appropriate level of heating if adjusted and maintained properly. The capricious readjustment of the zone thermostat caused the spaces to be randomly over- or underheated. Since the zone 3 interior temperatures were not well maintained and were not well matched between the two barracks, direct comparison between the relative energy consumption of the two zones was not possible.

Table 12 indicates that the DHW heating consumption was 16.3 percent higher in building 812 than in building 813 throughout the heating season. During week 10, this average difference was nearly the same as the seasonal average. However, during week 11, the higher DHW consumption declined to only 7.3 percent more than DHW for building 813. During this week, building 812 was nearly empty since

Table 12

Building 812 vs. 813 Test Reference— Direct Comparison of Total Site Energy Consumption

Building 812 vs 813 Test / Reference --
Direct Comparison of Total Site Energy Consumption.

		Data Summary		Energy Saved	Energy per Square Foot		Savings/ Sq.Ft.	Percent Savings
Energy Type	Date	Bldg 812 MBTU	Bldg 813 MBTU	Energy 812 vs 813 MBTU	Bldg 812 MBTU	Bldg 813 MBTU	812 vs 813 KBTU	812 vs 813 (%)
Gas Btus	8743-8809:	4885.01	5285.13	400.12	128.55	139.08	10.53	7.6%
	8810:	204.33	257.39	53.05	5.38	6.77	1.40	20.6%
	8811:	103.95	131.84	27.89	2.74	3.47	0.73	21.2%
	8810-8811 Total:	308.28	389.22	80.94	8.11	10.24	2.13	20.8%
Zone 3 Heat	8743-8809:	184.07	643.49	459.43	11.83	41.35	29.52	71.4%
	8810:	8.09	8.91	0.82	0.52	0.57	0.05	9.2%
	8811:	1.66	0.93	-0.72	0.11	0.06	-0.05	-77.4%
	8810-8811 Total:	9.75	9.85	0.10	0.63	0.63	0.01	1.0%
Zone 2 Heat	8743-8809:	878.85	466.44	-412.41	56.48	29.98	-26.50	-88.4%
	8810:	41.35	30.94	-10.42	2.66	1.99	-0.67	-33.7%
	8811:	4.84	1.31	-3.53	0.31	0.08	-0.23	-268.7%
	8810-8811 Total:	46.19	32.25	-13.95	2.97	2.07	-0.90	-43.2%
Zone 1 Heat	8743-8809:	1068.51	1060.74	-7.77	155.35	154.22	-1.13	-0.7%
	8810:	36.49	52.88	16.39	5.31	7.69	2.38	31.0%
	8811:	3.54	23.40	19.86	0.51	3.40	2.89	84.9%
	8810-8811 Total:	40.03	76.28	36.25	5.82	11.09	5.27	47.5%
Elec	8743-8809:	301.50	354.20	52.70	7.93	9.32	1.39	14.9%
	8810:	14.65	14.76	0.11	0.39	0.39	0.00	0.7%
	8811:	11.34	13.50	2.16	0.30	0.36	0.06	16.0%
	8810-8811 Total:	26.00	28.26	2.26	0.68	0.74	0.06	8.0%
DHW	8743-8809:	293.87	252.70	-41.18	7.73	6.65	-1.08	-16.3%
	8810:	17.55	15.06	-2.49	0.46	0.40	-0.07	-16.5%
	8811:	14.17	13.20	-0.97	0.37	0.35	-0.03	-7.3%
	8810-8811 Total:	31.72	28.26	-3.46	0.83	0.74	-0.09	-12.2%
Gas & Elec	8743-8809:	5186.51	5639.33	452.81	136.49	148.40	11.92	8.0%
	8810:	218.99	272.15	53.16	5.76	7.16	1.40	19.5%
	8811:	115.29	145.34	30.04	3.03	3.82	0.79	20.7%
	8810-8811 Total:	334.28	417.48	83.20	8.80	10.99	2.19	19.9%
Zone 1&2 Heat	8743-8809:	1947.35	1527.18	-420.18	62.57	49.07	-13.50	-27.5%
	8810:	77.84	83.81	5.97	2.50	2.69	0.19	7.1%
	8811:	8.38	24.72	16.33	0.27	0.79	0.52	66.1%
	8810-8811 Total:	86.23	108.53	22.30	2.77	3.49	0.72	20.6%
All Zones Heat	8743-8809:	2131.42	2170.67	39.25	56.09	57.12	1.03	1.8%
	8810:	85.93	92.73	6.79	2.26	2.44	0.18	7.3%
	8811:	10.04	25.65	15.61	0.26	0.68	0.41	60.9%
	8810-8811 Total:	95.97	118.38	22.40	2.53	3.12	0.59	18.9%

Key

Floor Space	38000	Sq. Ft. -- Elec, Gas & DHW (each)
	15561	Sq. Ft. -- Zones 1 & 2 (each)
	6878	Sq. Ft. -- Zone 3

Building 812 == Test
Building 813 == Reference

1 KBtu == 10^3 Btu
1 MBtu == 10^6 Btu

Week 8743 Starts 10/31/87
Week 8809 Starts 3/05/88
Week 8810 Starts 3/12/88
Week 8811 Starts 3/19/88

most troops in both resident companies were on maneuvers. Since the building was occupied by a relatively small number of troops during week 11 (about 20 compared with the typical 159), the DHW energy consumption was significantly lower than normal. This reduced DHW consumption appears to be correlated with occupancy levels in the building. Even though the regression analysis results indicated that the occupancy was not a good indicator of energy consumption, this short test period suggests that the occupancy does have an impact. The occupancy data were not provided in much detail by the resident companies during most of the heating season. This poor level of detail contributed to the lack of correlation between building occupancy and DHW energy consumption for the regression analysis.

Projected Savings

Since building 812 showed no significant energy savings with the EIFS retrofit based on the regression analysis, the energy savings attained during the 2-week improved operations test period were used to project the annual savings. Table 13 shows the consumption savings for heating and gas energy for building 812 compared with building 813 during the 2-week test. The table includes a projected annual gas and heating consumption and savings for the 1987/88 heating season and for an HDD normalized year (with 6415 HDD). These values were determined by taking the consumptions for the 2-week test period, dividing by the HDD in that period, and then multiplying by the 6095.7 HDD in 1987/88 or the 6415 HDD in a normal year for Colorado Springs.

The results of this projection indicate that the EIFS retrofit could save 354 MBtu or 18.9 percent of the heating energy required for a comparably operated and maintained, nonretrofit barracks building in the Colorado Springs climatic region (6415 HDD annually). The results suggest that the gas savings would be 1279 MBtu or 20.8 percent of the normalized annual gas consumption. The projected savings for the EIFS retrofit during the 1987/88 heating season were 336 MBtu of heating energy and 1215 MBtu of gas.

Table 13

Savings in Heating and Gas Energy for Buildings 812 and 813 During the 2-Week Improved Operations Test

	Reference Period	Bldg 812 (MBtu)	Bldg 813 (MBtu)	Bldg. 812 vs. 813 Savings (MBtu)	Bldg. 812 vs. 813 (Savings/sq ft) (MBtu/sq ft)	Bldg. 812 vs. 813 (%)
GAS ENERGY	2 week test 8810-8811 (4062 HDD)	308.3	389.2	80.9	2.13	20.6
	Projected 1987/88 Heating Season (6095.7 HDD)	4,626	5,841	1,215	32.0	20.6
	Normalized Heating Season (6415 HDD)	4,868	6,147	1,279	33.7	20.6
HEATING ENERGY	2 week test 8810-8811	96	118.4	22.4	0.59	18.9
	Projected 1987/88 Heating Season	1,440	1,776	336	8.8	18.9
	Normalized Heating Season	1,515	1,869	354	9.32	18.9

6 ECONOMIC ANALYSIS OF EIFS RETROFIT

Exterior insulation was identified as a cost-effective energy conservation retrofit for the Colorado Springs climatic region by Hittle et al. in TR E-183. The SIR for this building treatment exceeded the ECIP criteria for a cost-effective retrofit based on the energy savings, fuel costs, and construction costs assumed in that analysis.

The EIFS was installed on building 812 in FY86 and the energy performance test period occurred in FY87. The actual construction cost was nearly twice the projected cost. Anticipated annual energy savings were not realized except during the 2-week period of improved building operations. Since the actual construction cost and energy performance were quite different from what had been predicted, the actual cost and energy savings were evaluated to determine if the installed EIFS met ECIP criteria for a cost-effective energy conservation program.

Because the regression analysis was unable to identify significant energy savings as a result of the EIFS retrofit, the projected annual energy savings resulting from the 2-week improved operations test period were used for calculating the economics of this energy conservation retrofit. The economics of this retrofit were evaluated using project year actual construction costs and energy costs. The program was also evaluated based on a new estimate of the project year and current year construction costs.

Market scenarios were developed based on the ECIP criteria as well as energy and nonenergy factors from the Life Cycle Cost in Design (LCCID) program. The combinations of energy savings, fuel costs, maintenance and repair savings, and construction costs that satisfied the ECIP criteria were graphed.

Construction Cost, Actual and Estimates

The actual construction costs were based on U.S. Army Corps of Engineers (USACE) contract records for installation of the Insul/Crete polymer-modified EIFS on building 812 at Fort Carson. Construction cost estimates for the project year and current year were developed using the appropriate USACE and Dodge system unit price data, based on contractor submittals and as-built drawings. The LCCID computer program was used to calculate the SIR and simple payback for each of the scenarios based on ECIP criteria.

Detailed line item cost estimates for the current and project years are included in Appendix E. Table 14 summarizes these line item estimates.

Line 1 includes a complete estimate of costs for materials and labor to install the EIFS on the 14,916 sq ft exterior surface area of the L-shaped barracks. The price includes additional materials required for proper EIFS installation. No mechanical costs such as electrical, HVAC work, and controls were required for this energy conservation effort. The percentage rates for indirect costs, profit, and contingency are based on TM 5-800-2 (HQDA, June 1985).

The project year cost estimate was $94,339 compared with the actual cost of $140,770. Part of this difference may have been due to several factors that affect the accuracy of estimates and construction costs. For example, since the actual contractor profit and overhead were not available, this may have caused some of the variation in costs. In addition, the actual construction cost should have resulted from open competition in the free market. If there was less than an ideal level of competition for the job when it was advertised, this situation could explain the elevated construction cost.

Table 14

Project and Current Year Cost Estimates

Line Item	Project Year FY86 ($)	Current Year FY89 ($)
1. EIFS retrofit	68,066	66,228
2. Indirect costs, 20% of line 1	13,613	13,246
3. Profit, 5% of lines 1+2	4,084	3,974
4. Contingency, 10% of lines 1+2+3	8,576	8,348
5. Total estimate	94,339	91,794
6. Actual cost	140,770	

The current year cost estimate of $91,794 is even lower than the project year and actual construction costs. This difference is the result of a reduction in the regional cost of labor and materials to install the retrofit. If more EIFS were installed, it could be anticipated that the material costs would be reduced based on economies of scale.

Cost-Effectiveness of EIFS Retrofit

The cost-effectiveness of the retrofit, based on ECIP criteria, was evaluated by calculating the SIR and simple payback using the LCCID program. Cost-effectiveness was determined for: the project year with actual construction costs; the project year with estimated construction costs; and the current year (FY89) with estimated construction costs. The LCCID 1985 energy escalation rates were used for the project year estimates, and the 1987 escalation rates were used for the current year estimates. The energy savings were the projected annual energy savings based on the 2-week test period of improved building operations. The energy savings were reported in MBtu of natural gas. Gas costs were based on a weighted average cost of firm and interruptible gas at Fort Carson. Based on the nature of the EIFS retrofit and current Army maintenance policies, it was determined that no credit would initially be considered for reduced maintenance and repair costs to the building as a result of the retrofit. A life expectancy of 25 years for the EIFS retrofit was used for the calculations. This was the specified life expectancy for weatherization based on ECIP criteria. The results of the LCCID calculations are shown in Table 15. The LCCID printouts are included in Appendix F.

Table 15 indicates that, based on the actual construction costs, the EIFS retrofit does not meet the ECIP criterion of SIR ≥ 1 for the projected annual energy savings. The reduced construction cost estimate developed for the project year produces an SIR of 1.25, which does meet ECIP criterion. This result indicates that the retrofit would have been a cost-effective energy conservation measure with a 18.14-year simple payback period if the construction cost had matched the estimate. Even with the lower estimated construction cost in the current year (FY89), the ECIP criterion is not met since the SIR is only 0.98. The increase in payback period to 23.16 years in FY89 compared with the project year is due to the reduced cost of natural gas in the current year.

Painting the exterior block walls is required on a periodic basis. Based on current data (Neathammer, Neely, and Stirn), concrete block walls are refinished every 8 years on average. The high

Table 15

Cost Effectiveness of Retrofits

Energy Savings (MBtu/Yr)	Energy Cost ($/MBtu)	SIR	Simple Payback (Years)
Actual Construction Costs			
1279	4.08	0.84	27.07
Project Year Estimated Costs			
1279	4.08	1.25	18.14
Current Year Estimated Costs			
1279	3.11	0.98	23.16

frequency for repainting is every 6 years and the low frequency is 12 years. The average frequency and cost for repainting a three-story barracks building was input into LCCID as a nonrecurring cost savings that occurred at the eighth, sixteenth, and twenty-fourth years of a nonretrofit building. Based on unit cost data for repainting this type of building, the cost per occurrence was $15,617. This cost was input at 8-year intervals over the life of the building. It was assumed that the EIFS would require no repainting over the same period. This assumption was based on discussions with industry representatives since the EIFS was installed only 3 years ago and no long-term performance data are available. Table 16 documents the results of the LCCID runs, including cost savings for elimination of normal exterior painting cycles.

When the economic impact of the reduced frequency of exterior painting is included in the life cycle costs and savings associated with the EIFS retrofit, the SIR and simple payback are quite favorable for both the current and project years based on construction cost estimates. The actual cost of construction was high enough that the SIR was 0.96, which does not meet the ECIP criterion for a cost-effective energy conservation project (Table 16). The project year provides an SIR of 1.44 and a simple payback of 13.35 years. An EIFS installed in FY89 would provide an SIR of 1.17 and a simple payback of 15.74 years at Fort Carson. This is based on current gas costs of $3.11/MBtu, a projected annual energy savings of 1279 MBtu, and a regional installation cost of $91,794. The reduction in the SIR and the increased payback period for the current year over the project year are the result of a lower market price for natural gas.

Table 16

Cost Effectiveness of Retrofits When Reduced Painting Maintenance Is Considered

Energy Savings (MBtu/Yr)	Energy Cost ($/MBtu)	SIR	Simple Payback (Years)
Actual Construction Costs			
1279	4.08	0.96	19.92
Project Year Estimated Costs			
1279	4.08	1.44	13.35
Current Year Estimated Costs			
1279	3.11	1.17	15.74

The consideration of maintenance and repair (M&R) cost savings due to reduced exterior painting improves the cost-effectiveness of the EIFS retrofit. The added cost savings make the current year installation of the EIFS economically feasible, based on the ECIP criterion, with an SIR = 1.17. When the M&R savings were not included in the current year estimate, Table 15 indicates that the retrofit has an SIR < 1. During the project year, using estimated construction costs, the retrofit was determined to be cost-effective with or without considering reduced painting requirements. Other cost savings in construction or maintenance would have to accrue for the project to be feasible using actual construction cost figures.

Development of Market Scenarios

Market scenarios were developed to determine under what combination of conditions the EIFS retrofit would meet the ECIP criterion of SIR ≥ 1. The parameters used in this analysis were the construction cost, annual energy savings, natural gas fuel cost, and annual M&R savings. The scenarios were examined by developing an equation that expressed the relationship between the parameters when the ECIP criterion is satisfied. The parameters were defined as follows:

C_c = Construction cost
D_g = Gas energy discount factor
S_g = Annual gas energy cost savings
D_n = Nonenergy discount factor
S_n = Annual nonenergy savings

D_g is a discount factor that includes the time effects of the gas discount rate and energy cost escalation rate. These values were calculated by the LCCID program. The actual value is reported under item 2, column 4 (Discount Factor) in the LCCID printouts included in Appendix F.

From LCCID, Supervision and Inspection Overhead (SIOH) = 0.055 x C_c and Design Cost = 0.06 x C_c. Therefore, the total investment cost, $I_t = C_c + 0.055 \times C_c + 0.06 \times C_c = 1.115 \times C_c$. In the ECIP calculation, this total investment is given a 10 percent credit. Therefore, the final total investment for ECIP calculations is:

$$I_t = 0.9 \times (1.115) \times C_c = 1.0035 \times C_c \qquad \text{[Eq 1]}$$

The total discounted energy savings is expressed as:

$$E_t = D_g \times S_g \qquad \text{[Eq 2]}$$

The total discounted nonenergy savings due to M&R savings is:

$$N_t = D_n \times S_n \qquad \text{[Eq 3]}$$

For nonenergy savings, ECIP criteria state that only 25 percent of the total discounted savings, i.e., the sum of E_t and N_t, can be nonenergy savings. The mathematical representation of this condition is:

$$\text{Total discounted savings} = E_t + N_t \qquad \text{[Eq 4]}$$

where:

$$N_t/E_t = 0.25/0.75 \text{ or } N_t = 1/3 \times E_t \qquad \text{[Eq 5]}$$

Finally, the SIR can be expressed as:

$$SIR = \frac{\text{Total Discount Savings}}{\text{Total Investment}} = \frac{E_t + N_t}{I_t} \qquad \text{[Eq 6]}$$

or:

$$SIR = \frac{D_g \times S_g + D_n \times S_n}{1.0035 \times C_c} \qquad \text{[Eq 7]}$$

To satisfy the ECIP criteria, the SIR must be greater than or equal to 1. Setting SIR = 1, Equations 6 and 7 are rearranged to create the market scenarios:

$$C_c = \frac{D_g \times S_g + D_n \times S_n}{1.0035} \qquad \text{[Eq 8]}$$

and:

$$S_n \leq (1/3) \times \frac{D_g \times S_n}{D_n} \qquad \text{[Eq 9]}$$

If other types of energy were impacted by the retrofit, their discount factors and annual savings would also be included in the numerators of Equations 8 and 9. For this retrofit, only gas energy savings have been identified. The values of the discount factors D_g and D_n are 22.69 and 11.65, respectively, for the 25-year life. These values contain energy cost escalation effects for Colorado, which is within Department of Energy (DOE) Region 8 (Code of Federal Regulations (CFR), title 10, part 436, section A), and only apply to states in this same Region. These values are also based on the 1987 energy escalation rates. Substituting these values into Equations 8 and 9 yields:

$$C_c = \frac{22.69 \times S_g + 11.65 \times S_n}{1.0035} \qquad \text{[Eq 10]}$$

and:

$$S_n \leq 0.649 \times S_g$$

Figure 19 is a graphical representation of Equation 10. The lines represented by the square boxes are lines of constant fuel cost in dollars per MBtu as noted above each series of boxes. If a specific fuel cost and annual M&R savings are selected, then the graph can be used to determine the construction cost required to meet the ECIP criterion of SIR ≥ 1.0. The limitation on the annual nonenergy savings, S_n, is arbitrary. Cases for which S_n exceeds 0.649 x S_g may be very cost-effective, but must be funded under programs other than ECIP. For the initial case in which nonenergy savings are zero, this is not a factor in determining whether the project qualifies under ECIP.

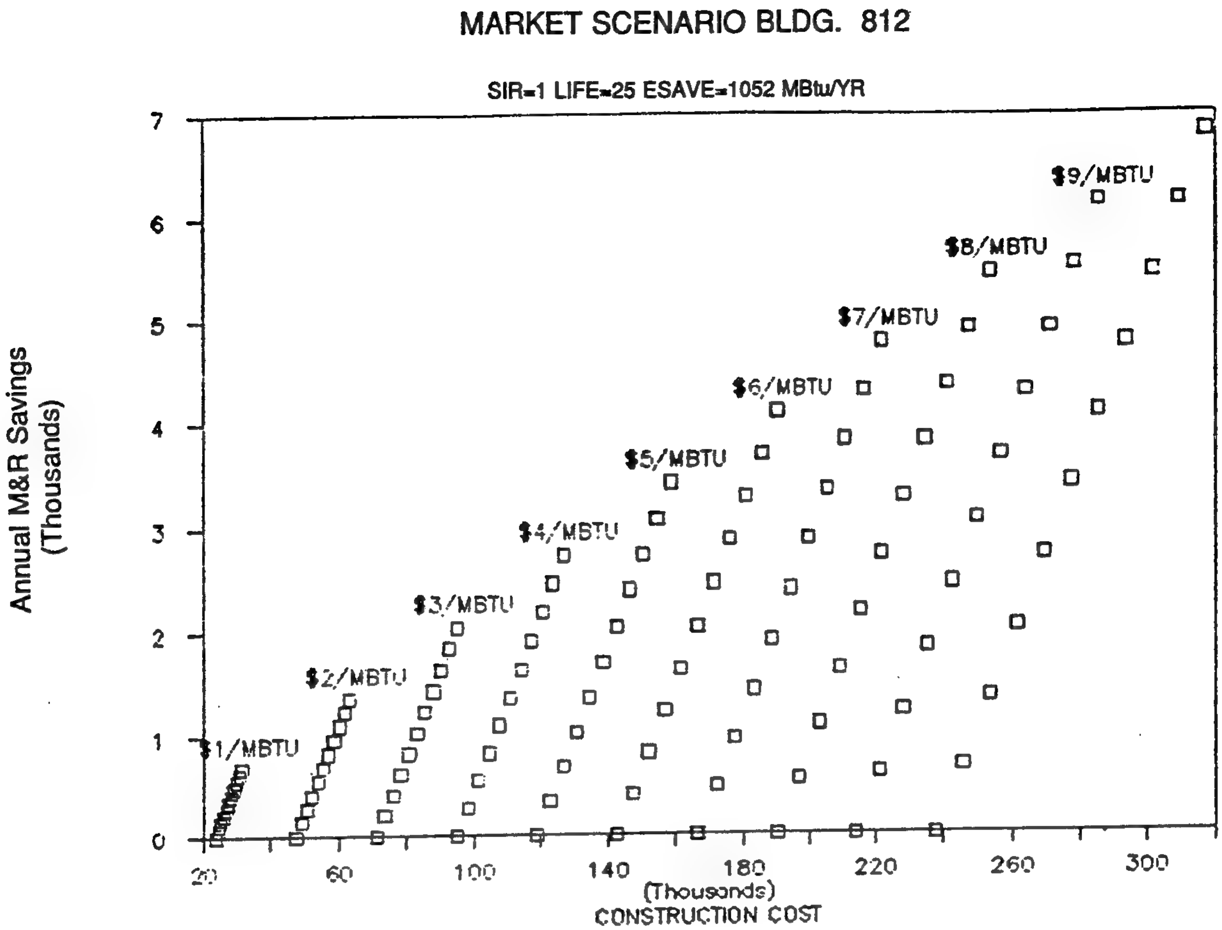


Figure 19. Equation Results Showing Market Scenario for SIR=1.

7 THERMOGRAPHIC EVALUATION OF EIFS INSTALLATION

Thermography uses an infrared (IR) imaging camera to monitor and record surface temperatures and variations in temperature across an object. Most thermographic equipment records the thermal radiation emitted by a surface between the 2.0 and 5.6 micrometer wavelength. Surface temperature distributions across a building exterior can be recorded. This information can provide valuable insights into the level of building wall insulation and air tightness of the structure (Pettersson and Bengt).

A thermographic system produced by Agema Infrared Systems was used to evaluate the relative improvement in the thermal integrity of barracks building 812, after retrofitting with the EIFS. The evaluation was intended to be strictly qualitative, since building monitoring equipment was inadequate to perform an accurate quantitative comparison of the change in the wall thermal resistance due to the EIFS retrofit. All IR thermographic evaluations were performed during the winter months when the building was experiencing a relatively stable, constant heating load and outdoor temperatures were well below freezing (typically below 15 °F). The evaluations were conducted before sunrise, between 0330 and 0630 hours. This procedure ensured that false building wall surface temperature measurements would be minimized, since the sun had not risen and the ground temperatures were typically at their lowest point for the 24-hr period. The IR reflection off the building from other sources such as the sun or warmer thermal masses (e.g., rocks or earth heated by the sun) could have caused major errors in the measured surface radiant temperature. Also, most of the thermographic imaging was performed with snow cover on the ground, which further reduced the risk of false thermographic readings.

The exterior surfaces of building 812 were scanned with the thermography equipment before the installation of the EIFS system to identify any unique thermal features of the building which should be compared with the retrofit wall thermal images. Buildings 812 and 813 were scanned after the retrofit was complete to provide a comparison of envelope losses of a retrofit and nonretrofit barracks building under identical weather conditions. The evaluation was limited to the building's exterior walls, including windows, utility service entrances, and other architectural details. Specifically, the evaluation was to determine whether the differences in levels of insulation could be detected with the IR equipment, detect poor installation practices, and determine whether thermography equipment could be used as an inspection tool for EIFS retrofit facilities.

When the insulation was installed on the building, the contract called for 2 in. of R-5 per inch insulation or a total insulation R-value of 10 to be applied to all exterior surfaces. The actual installation had 2 in. of insulation applied to all CMU walls; however, the contractor only applied 1 in. of insulation or R-5 to the concrete pilasters to maintain an esthetically pleasing appearance. The thermographic equipment easily detected the difference in surface temperature resulting from the lower insulation value installed on the pilasters. Figure 20 shows the relatively warmer pilaster (the whiter section in the middle of the photograph) with only 1 in. of insulation compared with the cooler (darker) surface of the CMU wall insulated with 2 in. of EPS foamboard insulation.

In addition to detecting differences in wall insulation levels, the thermography equipment allowed easy detection of several different poor installation details. At various locations around the building, openings allowed electric service conduits, coaxial television cables, or gas dryer vents to penetrate the walls. If the penetration had not been sealed properly, warm air could easily leak from the building through the opening. These poorly sealed openings appeared as hot spots (light colored areas) that were much warmer than the penetrations that had been properly sealed. Since these penetrations are such a small percentage of the total building envelope surface area, conduction losses through these penetrations is a minor concern. The major problem with these poorly sealed wall penetrations is the increased heat loss from infiltration of unconditioned outside air. Using the IR equipment, these leaks are readily identified.

Expansion joints that were not insulated also were easily detected with the thermographic equipment. These joints were neither insulated nor sealed to reduce air infiltration. The joints run the full height of the building, and there are typically two on each side of the building. These joints appeared as hot spots on the building wall scans and were at significantly higher temperatures than the rest of the exterior surfaces.

The BLAST analysis indicated that the combination of EIFS retrofit and reduced window area with new thermal-pane, thermal-break windows provided the best choice in building envelope retrofits to improve the envelope thermal performance. Since the window area is a significant portion of the building's exterior area, improving the thermal performance of these windows should reduce the overall envelope thermal losses.

The EIFS manufacturer recommends that full sheets of insulation be cut to fit each wall section and that no scrap material be used for insulating the building walls. The actual installation practice used by the contractor deviated somewhat from the manufacturer's specifications. In many wall sections, the insulation consisted of small pieces of insulation left over from cutouts on previous walls. All of the scraps were mechanically fastened to the CMU wall. However, there was some concern that this insulation installation practice might reduce the overall thermal insulating qualities of the EIFS. Areas where the insulation had been pieced together were noted and after the installation was complete, the wall section was scanned with the thermography camera. No significant differences in wall surface temperatures could be detected when compared with wall sections which contained continuous insulation sheets.

Fasteners are supposed to be placed in the EIFS system to mechanically fasten the insulation and fiberglass mesh to the existing CMU wall or concrete pilasters. The manufacturer recommends fasteners be installed at least every 16 in. horizontally and every 12 in. vertically on masonry walls. Since the fasteners used in the Insul/Crete system are plastic-covered metal, they are much better thermal conductors than the insulation that they penetrate. These thermal conductors or thermal bridges should result in a higher surface temperature where they are located compared with the surface temperature over the insulation. Thermography readily identified the fasteners after the concrete finish coats had been installed. Easy identification of location and proper spacing allowed verification of contractor compliance with manufacturer or industry fastener placement specifications.

The building thermographic evaluation allowed quick identification of major leaks due to poor sealing around expansion joints, utility entry points, or other wall penetrations. The evaluation showed that these leaks and the uninsulated windows were major contributors to building thermal conduction losses. To minimize these conduction losses, the contractor installation specifications should include requirements for proper sealing of the EIFS around all expansion joints and wall penetrations. Differences in relative levels of exterior wall insulation were identifiable using infrared thermography. Thermography may have applications for post-retrofit inspection before acceptance of the contractor's installation. Identification of adequate fastener placement and proper sealing of building penetrations ensures that the contractor is performing proper installation of the EIFS retrofit.

8 CONCLUSIONS AND RECOMMENDATIONS

The original intent of this project was to demonstrate the energy savings and economic feasibility of installing an EIFS on typically operated and maintained concrete block construction barracks. Most of the energy performance data gathered during the 1987/88 heating season indicated that the retrofit did not save energy and would not meet ECIP criteria as a cost-effective energy conservation project on buildings that receive similar levels of M&R. The results of this energy savings evaluation on a normally operated and maintained building are very significant because many energy conservation retrofits are justified and initiated assuming perfect or proper operation of the facility. Energy savings calculations are based on engineering studies with little or no specific data on how well the building is operating. This study has demonstrated that if the building is not properly designed, operated, or maintained, the actual energy savings realized from any energy conservation project may be much less than the engineering studies predict. These results suggest that great care must be taken to ensure that the assumptions made about building design, usage, and operation match the actual facility when evaluating energy conservation alternatives.

The data analysis and regression models developed for the 1987/88 heating season suggest that the EIFS retrofit provided no quantifiable energy savings on building 812 compared with control building 813. However, problems with maintaining reasonable interior comfort conditions, poor mechanical system and control design for present building usage, and maintenance practices appeared to mask any potential energy savings resulting from the retrofit during most of the test heating season. Interior temperatures averaged 78 °F in building 812 during the heating season and zone temperatures above 90 °F were observed on many occasions. This excessive interior temperature forced occupants to open windows in an attempt to attain reasonable comfort. Many windows were left open on the coldest days, causing major reductions in the overall building thermal efficiency. Improper heating system control settings and air entrapment in the hydronic heating system plumbing loops compounded occupant comfort problems.

The 2-week improved operations test period produced lower interior temperatures and decreased the number of window openings. The building performance data for this period indicate that the EIFS retrofit can provide significant gas and heating energy savings compared with a similar, uninsulated barracks when the facilities are operated and maintained properly. The gas energy consumption was 20.8 percent lower for the EIFS retrofit barracks than the nonretrofit facility during this test period. The projected annual savings were 1279 MBtu of gas for the 1987/88 heating season. This gas energy savings is more than the 800 MBtu predicted by the BLAST analysis for the Colorado Springs location. Interior temperatures remained above normal comfort levels during this 2-week test. If the mechanical system had been designed, controlled, and maintained properly, additional energy savings might have been realized for the EIFS retrofit.

The projected annual gas savings with improved building operation make the EIFS retrofit a cost-effective project, based on ECIP criteria, for the project year cost estimate. The project was not cost effective based on the actual construction cost incurred for this demonstration. However, the actual cost of installing the Class PM system was much higher than the industry standard cost per square foot for installing either a Class PM or Class PB EIFS. The reconstructed project year cost estimate and projected improved operations energy savings make the retrofit cost effective with a simple payback of 13.3 years. The current year construction cost is lower than the project year estimate, but lower fuel costs reduce the SIR to 0.98. The current year project would not qualify unless the maintenance and repair cost savings for reduced painting frequency are considered, or the less expensive Class PB system were selected. If savings associated with the elimination of exterior painting are included in the economic analysis, both the project year and current year project would qualify for ECIP funding. The EIFS retrofit may be even

more cost effective if energy prices escalate or if EIFS installation costs are decreased due to economic forces or selection of the Class PB system.

Infrared thermographic imaging equipment was used to monitor the thermal characteristics of the control and retrofit building envelopes. The images allow easy detection of areas of poor insulation value such as building penetrations that have not been sealed properly. Thermographic analysis may also have useful application in acceptance testing to verify the contractors' installation practices. This is particularly valuable for Class PM systems where fastener location may be critical to long term EIFS durability.

The energy savings estimates resulting from this experiment could only be considered an accurate predictor of the expected energy savings for EIFS retrofitted L-shaped barracks in the same climatic region with similar mechanical system characteristics and O&M practices. These results cannot be interpreted for dissimilar buildings or for other climatic zones with the same retrofit.

The results of this experiment indicate that the Class PM EIFS retrofit should not be the first priority when considering energy conservation alternatives. For the EIFS to be a cost-effective retrofit, the building controls and mechanical system must be designed and operated properly. First priority should be to ensure that the building is providing energy-efficient comfort to its occupants.

Based on these findings, the following recommendations are made:

1. Before a facility is considered a candidate for an EIFS retrofit, it should be evaluated to ensure that the mechanical system is designed and operating properly and is meeting comfort requirements for the occupants.

2. Proper general building maintenance and adequate building performance refinement should always be ensured before considering major energy conservation retrofits such as the EIFS.

3. Less capital-intensive energy conservation projects than EIFS should be implemented to ensure that the building is operating efficiently (e.g., controller tuning and maintenance, boiler tuning, improved periodic maintenance of mechanical equipment).

4. The EIFS should be specified adequately and the installation monitored to ensure that it adheres to industry and manufacturer standards. This specification should clearly define whether the EIFS requested is a Class PB or Class PM system.

5. When evaluating the economics of an EIFS project, consideration should be given to the system's effects in improving the building thermal efficiency and reducing the heating requirements. This condition may adversely affect the mechanical system efficiency by reducing part-load efficiency.

6. Before the results of this experiment can be used to accurately predict the potential savings of retrofitting the EIFS on L-shaped barracks in other climatic regions, additional studies of retrofit barracks in at least two other regions are required.

7. If additional EIFS energy evaluations are initiated using the test-reference method, the test should include a 1-year calibration period (before installing the EIFS) to account for inherent differences in building energy performance. This procedure will help improve accuracy when determining the actual energy savings resulting from the EIFS.

8. Longer term testing should be done to validate the annual savings projected from the short 2-week test period with improved operations.

9. Additional testing is needed to determine how much of the energy savings can be attributed to the EIFS retrofit compared with how the other variables such as building occupancy, ventilation of occupied spaces, mechanical system design, and control system O&M impact building energy consumption. This testing would help accurately determine the appropriate priority of energy conservation efforts based on potential energy savings and other economic factors. This testing should include an energy performance test of Class PB and Class PM systems to compare differences in energy savings. This will also provide data to determine which system is more cost effective from an energy standpoint.

10. USACE designers should understand the building prerequisites necessary to ensure that an EIFS retrofit meets ECIP criteria and is an appropriate choice for an energy conservation project.

METRIC CONVERSION TABLE

1 Btu	=	1.055 kJ
1 in.	=	2.54 cm
1 sq ft	=	0.092 m^2
°F	=	(°C x 1.8) + 32

REFERENCES

Code of Federal Regulations, 10CFR 436A (1987).

Department of the Army Pamphlet (DA PAM) 600-45, *Army Communities of Excellence* (Headquarters, Department of the Army [HQDA], October 1988).

Herron, D., G. Walton, and L. Lawrie, *Building Loads Analysis and System Thermodynamics (BLAST) Program User's Manual, Vol I Supplement, Version 3.0*, TR E-171/ADA099054 (USACERL, March 1981).

Hittle, D.C., *The Building Loads Analysis and System Thermodynamics (BLAST) Program, Version 2.0, User's Manual, Vols I and II*, TR E-153/ADA072272 and ADA072273 (USACERL, June 1979).

Hittle, D.C., R.E. O'Brien, and G.S. Percivall, *Analysis of Energy Conservation Alternatives for Standard Army Buildings*, TR E-183/ADA129963 (USACERL, March 1983).

Neathammer, R.D., E.S. Neely, and J.R. Stirn, *Building Maintenance and Repair Data for Life-Cycle Cost Analysis: Architectural Systems*, Draft Special Report (USACERL, July 1989).

Nie, N.H., et al., *Statistical Package for the Social Sciences*, 2nd ed. (McGraw-Hill, 1975).

Office of the Chief of Engineers, letter, subject: Energy Conservation Investment Program Guidance (25 April 1988).

Pettersson, B., and A. Bengt. *Thermography, Testing of the Thermal Insulation and Airtightness of Buildings* (Swedish Council for Building Research).

Technical Manual (TM) 5-785, *Engineering Weather Data* (HQDA, 1 July 1978).

TM 5-800-2, *Cost Estimates: Military Construction* (HQDA, 12 June 1985).

Westervelt, E.T., G.R. Northrup, and E.O. Allen, *Applying Energy Conservation Retrofits to Standard Army Buildings: Project Design and Initial Energy Data*, Interim Report E-88/08/ADA198953 (USACERL, July 1988).

APPENDIX A: Results of Regression Analysis With Natural Gas Consumption as Dependent Variable

The SPSS software was used to run regression analysis on the building energy consumption data as described in Chapter 5. The detailed printouts of these SPSS runs on the data for buildings 812 and 813 are included in this appendix. All printouts are from stepwise and multiple regression analyses using daily natural gas consumption as the dependent variable. All variables used or considered for the regression runs are listed. Independent variables used in the final regression runs are listed along with their respective correlation/covariance matrices and other statistics on all variables included in the regression models.

Variable Names for L-Shaped Barracks - Gas

Variable	Units	Description
NDATE	None	Date in Lotus Symphony format.
ELMSM	KWH	Daily electricity consumption.
GASMSM	BTU	Daily gas consumption.
BTU3SM	BTU	Daily heating consumption for zone 3.
BTU2SM	BTU	Daily heating consumption for zone 2.
BTU1SM	BTU	Daily heating consumption for zone 1.
BTUDHWSM	BTU	Daily domestic hot water energy consumption.
BTUCLGSM	BTU	Daily cooling energy consumption.
T1EAV	°F	Daily average temperature, zone 1 east.
T1WAV	°F	Daily average temperature, zone 1 west.
T2EAV	°F	Daily average temperature, zone 2 east.
T2WAV	°F	Daily average temperature, zone 2 west.
T3EAV	°F	Daily average temperature, zone 3 east.
T3WAV	°F	Daily average temperature, zone 3 west.
TMHAV	°F	Daily average temperature, mess hall.
ELMN	None	Number of hourly values included in ELMSM.
GASMN	None	Number of hourly values included in GASMSM.
BTU3N	None	Number of hourly values included in BTU3SM.
BTU2N	None	Number of hourly values included in BTU2SM.
BTU1N	None	Number of hourly values included in BTU1SM.
BTUDHWN	None	Number of hourly values included in BTUDHWSM.
BTUCLGN	None	Number of hourly values included in BTUCLGSM.
MOAT	°F	Daily average outdoor air temperature, building 811, from building 811 data file.
COUNT	None	Count of hourly data points included in daily total.
OATAV	°F	Daily average outdoor air temperature, average of buildings 811, 812, and 813, from outdoor air temperature file.
MOATAV	°F	Daily average outdoor air temperature, building 811, from outdoor air temperature file.
NOATAV	°F	Daily average outdoor air temperature, building 812, from outdoor air temperature file.
OOATAV	°F	Daily average outdoor air temperature, building 813, from outdoor air temperature file.
OATN	None	Number of hourly values included in OATAV.
MOATN	None	Number of hourly values included in MOATAV.
NOATN	None	Number of hourly values included in NOATAV.
OOATN	None	Number of hourly values included in OOATAV.
TALLMAV	°F	Average of T1EAV, T1WAV, T2EAV, T2WAV, T3EAV, T3WAV, and TMHAV.

The variable names listed above are those used for building 811. Buildings 812 and 813 used similar names, except that an N or an O was added to the name for buildings 812 and 813, respectively.

Data Included If: Gas > 50,000 BTU,
Daily Average Outdoor Air Temperature < = 65°F, and
For building 811, date not 1/2/87.

```
The SPSS/PC+ system file is read from
    file d:\n\sys\nbas1.sys
The file was created on  8/19/88 at  9:14:59
and is titled L-Shaped - N - Replaced Data
The SPSS/PC+ system file contains
    632 cases, each consisting of
     35 variables (including system variables).
     35 variables will be used in this session.
--------------------------------------------------------------------------------
Page   2   Building 812 - prior to September, 1987 - Heating            11/22/88

This procedure was completed at 14:32:37
The raw data or transformation pass is proceeding
    292 cases are written to the uncompressed active file.
--------------------------------------------------------------------------------
Page   3   Building 812 - prior to September, 1987 - Heating            11/22/88


Number of Valid Observations (Listwise) =       246.00
```

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31749.97	136.57	31472.00	32020.00	292	
ELNSM	658.51	68.35	431.09	821.13	292	
GASNSM	29028153	13590440.1	3007600	58032260	292	
BTU3NSM	695023.99	754558.90	-152732	3900926	269	
BTU2NSM	3996119.0	3056827.40	.00	9661266	269	
BTU1NSM	4019770.5	3488546.90	.00	11008842	269	
BTUDHWNS	2365053.1	633829.77	513924.6	4463644	292	
BTUCLGNS	-308627.4	877180.12	-1203635	10372560	289	
T1ENAV	76.93	3.98	64.48	84.90	292	
T1WNAV	78.31	5.47	65.36	88.89	292	
T2ENAV	77.26	4.79	62.22	86.05	292	
T2WNAV	77.87	4.41	68.66	89.21	292	
T3ENAV	78.23	4.35	68.02	93.04	292	
T3WNAV	76.13	4.83	65.60	90.71	292	
TMHNAV	77.49	5.23	64.80	91.77	292	
ELNN	24.00	.00	24.00	24.00	292	
GASNN	24.00	.00	24.00	24.00	292	
BTU3NN	24.00	.00	24.00	24.00	292	
BTU2NN	24.00	.00	24.00	24.00	292	
BTU1NN	24.00	.00	24.00	24.00	292	
BTUDHWNN	24.00	.00	24.00	24.00	292	
BTUCLGNN	24.00	.00	24.00	24.00	292	
NOAT	47.35	11.92	11.60	65.39	292	
COUNT	23.83	.38	23	24	292	
OATAV	46.47	12.21	11.41	64.99	292	
MOATAV	45.56	12.85	10.59	72.11	278	
NOATAV	47.39	11.91	11.60	65.39	292	
OOATAV	45.40	12.45	11.15	65.97	271	
OATN	23.82	.38	23	24	292	
MOATN	21.60	6.10	0	24	292	
NOATN	23.65	.51	21	24	292	
OOATN	20.85	7.01	0	24	292	
TALLNAV	77.46	4.01	67.54	85.21	292	

```
--------------------------------------------------------------------------------
Page   4   Building 812 - prior to September, 1987 - Heating            11/22/88

This procedure was completed at 14:33:08
```

Page 5 Building 812 - prior to September, 1987 - Heating 11/22/88

**** M U L T I P L E R E G R E S S I O N ****

Listwise Deletion of Missing Data

N of Cases = 292

Correlation, Covariance:

	GASNSM	OATAV	TALLNAV	BTUDHWNS
GASNSM	1.000 184700063313717	-.649 -107692184.877	.470 25570365.360	.538 4636966366231.3
OATAV	-.649 -107692184.877	1.000 149.037	.162 7.940	-.394 -3050697.594
TALLNAV	.470 25570365.360	.162 7.940	1.000 16.057	.118 299315.003
BTUDHWNS	.538 4636966366231.3	-.394 -3050697.594	.118 299315.003	1.000 401740181535.62

Page 6 Building 812 - prior to September, 1987 - Heating 11/22/88

**** M U L T I P L E R E G R E S S I O N ****

Equation Number 1 Dependent Variable.. GASNSM

Beginning Block Number 1. Method: Enter OATAV TALLNAV BTUDHWNS

Variable(s) Entered on Step Number 1.. BTUDHWNS
2.. TALLNAV
3.. OATAV

Multiple R	.89361		
R Square	.79854	R Square Change	.79854
Adjusted R Square	.79644	F Change	380.52841
Standard Error	6131616.5618	Signif F Change	.0000

F = 380.52841 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUDHWNS	4.62995	.62987	3.39021	5.86968	.21593	.81060	7.351	.0000
TALLNAV	1865735.5961	92790.47603	1683102.1099	2048369.0823	.55011	.93451	20.107	.0000
OATAV	-727206.7868	32910.69090	-791982.7689	-662430.8048	-.65324	.80037	-22.096	.0000
(Constant)	-92651149.83	6996386.009	-106421683.4	-78880616.23			-13.243	.0000

End Block Number 1 All requested variables entered.

Page 7 Building 812 - prior to September, 1987 - Heating 11/22/88

This procedure was completed at 14:33:15
The SPSS/PC+ system file is read from
file d:\n\sys\nbas1.sys
The file was created on 8/19/88 at 9:14:59
and is titled L-Shaped - N - Replaced Data
The SPSS/PC+ system file contains
632 cases, each consisting of
35 variables (including system variables).
35 variables will be used in this session.

Page 8 Building 812 - after August, 1987 - Heating 11/22/88

This procedure was completed at 14:33:18
The raw data or transformation pass is proceeding
189 cases are written to the uncompressed active file.

Page 9 Building 812 - after August, 1987 - Heating 11/22/88

Number of Valid Observations (Listwise) = 147.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	32142.34	68.35	32025.00	32262.00	189	
ELNSM	622.83	86.16	346.99	766.46	189	
GASNSM	28604042	12400755.3	4212700	47029800	189	
BTU3NSM	834582.98	796763.45	-76196.5	2307655	189	
BTU2NSM	4098712.3	3514425.79	.00	10288930	189	
BTU1NSM	4813114.5	4271514.08	.00	10816812	189	
BTUDHWNS	2006162.5	578691.03	308156.2	3225652	189	
BTUCLGNS	15111.17	147665.21	-484.34	1439505	189	
T1ENAV	78.22	4.18	68.57	84.64	189	
T1WNAV	79.15	5.56	67.02	89.44	189	
T2ENAV	77.23	3.60	68.74	83.50	189	
T2WNAV	75.35	3.75	67.79	84.99	189	
T3ENAV	76.61	3.15	68.75	84.13	189	
T3WNAV	73.49	3.39	66.83	81.08	189	
TMHNAV	77.28	4.66	67.38	89.44	189	
ELNN	24.00	.00	24.00	24.00	189	
GASNN	24.00	.00	24.00	24.00	189	
BTU3NN	24.00	.00	24.00	24.00	189	
BTU2NN	24.00	.00	24.00	24.00	189	
BTU1NN	24.00	.00	24.00	24.00	189	
BTUDHWNN	24.00	.00	24.00	24.00	189	
BTUCLGNN	24.00	.00	24.00	24.00	189	
NOAT	41.29	13.29	10.16	64.72	189	
COUNT	23.85	.36	23	24	189	
OATAV	41.28	12.80	12.24	63.34	189	
MOATAV	40.51	12.00	14.64	62.42	168	
NOATAV	41.35	13.31	10.16	64.72	189	
OOATAV	42.41	12.40	8.14	64.15	159	
OATN	23.83	.38	23	24	189	
MOATN	19.89	8.11	0	24	189	
NOATN	23.76	.43	23	24	189	
OOATN	17.83	9.62	0	24	189	
TALLNAV	76.76	3.43	68.46	83.85	189	

Page 10 Building 812 - after August, 1987 - Heating 11/22/88

This procedure was completed at 14:33:45

Page 11 Building 812 - after August, 1987 - Heating 11/22/88

* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

N of Cases = 189

Correlation, Covariance:

	GASNSM	OATAV	TALLNAV	BTUDHWNS
GASNSM	1.000 153778732176983	-.738 -117232022.014	.652 27715486.080	.446 3203107493127.5
OATAV	-.738 -117232022.014	1.000 163.885	-.092 -4.050	-.437 -3240467.997
TALLNAV	.652 27715486.080	-.092 -4.050	1.000 11.755	.204 405021.725
BTUDHWNS	.446 3203107493127.5	-.437 -3240467.997	.204 405021.725	1.000 334883303953.10

Page 12 Building 812 - after August, 1987 - Heating 11/22/88

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. GASNSM

Beginning Block Number 1. Method: Enter OATAV TALLNAV BTUDHWNS

Variable(s) Entered on Step Number 1.. BTUDHWNS
2.. TALLNAV
3.. OATAV

Multiple R	.94336		
R Square	.88992	R Square Change	.88992
Adjusted R Square	.88814	F Change	498.53767
Standard Error	4147565.0278	Signif F Change	.0000

F = 498.53767 Signif F = .0000

------------------------------------ Variables in the Equation ------------------------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUDHWNS	.73794	.59125	-.42852	1.90439	.03444	.78162	1.248	.2136
TALLNAV	2108819.2202	90124.22941	1931015.8324	2286622.6079	.58305	.95832	23.399	.0000
OATAV	-648630.8230	26276.13252	-700470.2164	-596791.4296	-.66961	.80866	-24.685	.0000
(Constant)	-107975121.5	6977554.653	-121740929.7	-94209313.31			-15.475	.0000

End Block Number 1 All requested variables entered.

Page 13 Building 812 - after August, 1987 - Heating 11/22/88

This procedure was completed at 14:33:54

```
The SPSS/PC+ system file is read from
    file d:\o\sys\obas1.sys
The file was created on  8/18/88 at 14:27:00
and is titled L-Shaped - 0 - Replaced Data
The SPSS/PC+ system file contains
    584 cases, each consisting of
     35 variables (including system variables).
     35 variables will be used in this session.
-----------------------------------------------------------------------------
Page   2   Building 813 - prior to September, 1987 - Heating           11/22/88

This procedure was completed at 14:42:27
The raw data or transformation pass is proceeding
    289 cases are written to the uncompressed active file.
-----------------------------------------------------------------------------
Page   3   Building 813 - prior to September, 1987 - Heating           11/22/88


Number of Valid Observations (Listwise) =        233.00

Variable       Mean    Std Dev   Minimum   Maximum       N  Label

NDATE      31744.69     142.59  31416.00  32020.00     289
ELOSM        590.17      44.37    433.34    783.82     289
GASOSM     27453367 10913026.0   2698600  48000000     289
BTU3OSM   363801.41  619999.80   -235512   2198591     254
BTU2OSM   2788822.9 2015274.37   -183498   7235829     269
BTU1OSM   4425423.5 3192089.47       .00  10819161     269
BTUDHWOS  2208015.3  751401.47  711831.6   3925908     289
BTUCLGOS   57312.41  180472.14   -317784   1504873     289
T1EOAV        76.58       3.42     65.05     89.80     289
T1WOAV        77.75       3.83     66.81     90.71     289
T2EOAV        75.39       3.01     64.70     84.54     289
T2WOAV        77.72       3.28     66.01     86.28     289
T3EOAV        73.96       3.40     63.29     83.73     289
T3WOAV        76.50       3.65     66.21     84.54     289
TMHOAV        74.45       5.31     60.68     88.82     289
ELON          24.00        .00     24.00     24.00     289
GASON         24.00        .00     24.00     24.00     289
BTU3ON        24.00        .00     24.00     24.00     289
BTU2ON        24.00        .00     24.00     24.00     289
BTU1ON        24.00        .00     24.00     24.00     289
BTUDHWON      24.00        .00     24.00     24.00     289
BTUCLGON      24.00        .00     24.00     24.00     289
OOAT          45.39      12.72     11.15     65.16     289
COUNT         23.87        .34        23        24     289
OATAV         45.60      12.54     11.41     64.91     289
MOATAV        44.95      13.15     10.59     72.11     274
NOATAV        46.02      12.22     11.60     71.66     271
OOATAV        45.43      12.71     11.15     65.50     289
OATN          23.86        .35        23        24     289
MOATN         21.37       6.35         0        24     289
NOATN         21.48       6.35         0        24     289
OOATN         23.66        .48        22        24     289
TALLOAV       76.05       3.07     66.22     85.85     289
-----------------------------------------------------------------------------
Page   4   Building 813 - prior to September, 1987 - Heating           11/22/88

This procedure was completed at 14:42:58
```

Page 5 Building 813 - prior to September, 1987 - Heating 11/22/88

**** M U L T I P L E R E G R E S S I O N ****

Listwise Deletion of Missing Data

N of Cases = 289

Correlation, Covariance:

	GASOSM	OATAV	TALLOAV	BTUDHWOS
GASOSM	1.000 119094137430059	-.763 -104508687.667	.090 3005255.381	.560 4592434667865.3
OATAV	-.763 -104508687.667	1.000 157.328	.403 15.540	-.497 -4688507.505
TALLOAV	.090 3005255.381	.403 15.540	1.000 9.439	-.017 -39851.566
BTUDHWOS	.560 4592434667865.3	-.497 -4688507.505	-.017 -39851.566	1.000 564604171522.81

Page 6 Building 813 - prior to September, 1987 - Heating 11/22/88

**** M U L T I P L E R E G R E S S I O N ****

Equation Number 1 Dependent Variable.. GASOSM

Beginning Block Number 1. Method: Enter OATAV TALLOAV BTUDHWOS

Variable(s) Entered on Step Number 1.. BTUDHWOS
2.. TALLOAV
3.. OATAV

Multiple R	.88535		
R Square	.78384	R Square Change	.78384
Adjusted R Square	.78156	F Change	344.48619
Standard Error	5100446.4729	Signif F Change	.0000

F = 344.48619 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUDHWOS	1.90000	.47390	.96722	2.83278	.13082	.71238	4.009	.0001
TALLOAV	1584589.0644	109875.4835	1368318.6632	1800859.4656	.44610	.79269	14.422	.0000
OATAV	-764174.4387	31019.11282	-825230.0606	-703118.8169	-.87831	.59671	-24.636	.0000
(Constant)	-62407437.95	7733159.461	-77628790.75	-47186085.14			-8.070	.0000

End Block Number 1 All requested variables entered.

Page 7 Building 813 - prior to September, 1987 - Heating 11/22/88

This procedure was completed at 14:43:05
The SPSS/PC+ system file is read from
file d:\c\sys\obas1.sys
The file was created on 8/18/88 at 14:27:00
and is titled L-Shaped - 0 - Replaced Data
The SPSS/PC+ system file contains
584 cases, each consisting of
35 variables (including system variables).
35 variables will be used in this session.

Page 8 Building 813 - after August, 1987 - Heating 11/22/88

This procedure was completed at 14:43:07
The raw data or transformation pass is proceeding
153 cases are written to the uncompressed active file.

Page 9 Building 813 - after August, 1987 - Heating 11/22/88

Number of Valid Observations (Listwise) = 141.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	32149.64	72.34	32029.00	32262.00	153	
ELOSM	593.16	56.28	429.71	714.16	153	
GASOSM	25917199	10991464.0	3635900	46535400	153	
BTU3OSM	357536.01	592632.95	-53457.2	2036385	153	
BTU2OSM	2532132.8	2162263.75	-138694	7349898	153	
BTU1OSM	4784791.7	3079602.01	.00	10405000	153	
BTUDHWOS	1608734.5	470742.42	717176.2	2914026	153	
BTUCLGOS	-45735.91	263762.36	-1916580	112370.9	153	
T1EOAV	74.38	3.68	67.06	84.88	153	
T1WOAV	76.31	3.69	66.98	83.37	153	
T2EOAV	75.49	3.02	68.83	80.99	153	
T2WOAV	75.60	2.93	67.51	81.36	153	
T3EOAV	72.76	2.89	66.75	79.18	153	
T3WOAV	75.13	3.07	66.12	82.66	153	
TMHOAV	74.30	5.38	59.26	83.59	153	
ELON	24.00	.00	24.00	24.00	153	
GASON	24.00	.00	24.00	24.00	153	
BTU3ON	24.00	.00	24.00	24.00	153	
BTU2ON	24.00	.00	24.00	24.00	153	
BTU1ON	24.00	.00	24.00	24.00	153	
BTUDHWON	24.00	.00	24.00	24.00	153	
BTUCLGON	24.00	.00	24.00	24.00	153	
OOAT	42.77	12.13	12.85	63.34	153	
COUNT	23.80	.40	23	24	153	
OATAV	42.46	12.47	12.24	63.34	153	
MOATAV	41.69	12.13	14.64	61.95	144	
NOATAV	42.19	12.84	10.16	64.72	150	
OOATAV	42.83	12.16	12.85	63.34	153	
OATN	23.80	.40	23	24	153	
MOATN	21.56	6.34	0	24	153	
NOATN	22.42	4.72	0	24	153	
OOATN	23.69	.46	23	24	153	
TALLOAV	74.85	2.72	67.84	80.67	153	

Page 10 Building 813 - after August, 1987 - Heating 11/22/88

This procedure was completed at 14:43:32

Page 11 Building 813 - after August, 1987 - Heating 11/22/88

**** M U L T I P L E R E G R E S S I O N ****

Listwise Deletion of Missing Data

N of Cases = 153

Correlation, Covariance:

	GASOSM	OATAV	TALLOAV	BTUDHWOS
GASOSM	1.000 120812281443539	-.862 -118100265.404	.196 5872619.454	.505 2611536567632.2
OATAV	-.862 -118100265.404	1.000 155.532	.197 6.671	-.433 -2544694.159
TALLOAV	.196 5872619.454	.197 6.671	1.000 7.410	-.098 -124967.387
BTUDHWOS	.505 2611536567632.2	-.433 -2544694.159	-.098 -124967.387	1.000 221598428225.48

Page 12 Building 813 - after August, 1987 - Heating 11/22/88

**** M U L T I P L E R E G R E S S I O N ****

Equation Number 1 Dependent Variable.. GASOSM

Beginning Block Number 1. Method: Enter OATAV TALLOAV BTUDHWOS

Variable(s) Entered on Step Number 1.. BTUDHWOS
2.. TALLOAV
3.. OATAV

Multiple R	.95083		
R Square	.90407	R Square Change	.90407
Adjusted R Square	.90214	F Change	468.07596
Standard Error	3438426.5060	Signif F Change	.0000

F = 468.07596 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUDHWOS	3.91018	.65749	2.61097	5.20938	.16747	.81196	5.947	.0000
TALLOAV	1544064.0237	104499.3229	1337571.9839	1750556.0635	.38241	.96120	14.776	.0000
OATAV	-761586.5627	25190.54990	-811363.4214	-711809.7040	-.86412	.78810	-30.233	.0000
(Constant)	-63614755.30	7863985.387	-79154094.10	-48075416.50			-8.089	.0000

End Block Number 1 All requested variables entered.

Page 13 Building 813 - after August, 1987 - Heating 11/22/88

This procedure was completed at 14:43:37

APPENDIX B:

RESULTS OF REGRESSION ANALYSIS WITH HEATING ENERGY AS DEPENDENT VARIABLE

The SPSS software was used to run regression analysis on the building heating energy consumption data as described in Chapter 5. The detailed printouts of these SPSS runs on the data for buildings 812 and 813 are included in this appendix. All printouts are from stepwise and multiple regression analyses using daily building heating energy consumption as the dependent variable. All variables used or considered for the regression runs are listed. Independent variables used in the final regression runs are listed along with their respective correlation/covariance matrices and other statistics on all variables included in the regression models.

Variable Names For L-Shaped Barracks - Heating

Variable	Units	Description
NDATE	None	Date in Lotus Symphony format.
ELMSM	KWH	Daily electricity consumption.
GASMSM	BTU	Daily gas consumption.
BTU3SM	BTU	Daily heating consumption for zone 3.
BTU2SM	BTU	Daily heating consumption for zone 2.
BTU1SM	BTU	Daily heating consumption for zone 1.
BTUDHWSM	BTU	Daily domestic hot water energy consumption.
BTUCLGSM	BTU	Daily cooling energy consumption.
T1EAV	°F	Daily average temperature, zone 1 east.
T1WAV	°F	Daily average temperature, zone 1 west.
T2EAV	°F	Daily average temperature, zone 2 east.
T2WAV	°F	Daily average temperature, zone 2 west.
T3EAV	°F	Daily average temperature, zone 3 east.
T3WAV	°F	Daily average temperature, zone 3 west.
TMHAV	°F	Daily average temperature, mess hall.
ELMN	None	Number of hourly values included in ELMSM.
GASMN	None	Number of hourly values included in GASMSM.
BTU3N	None	Number of hourly values included in BTU3SM.
BTU2N	None	Number of hourly values included in BTU2SM.
BTU1N	None	Number of hourly values included in BTU1SM.
BTUDHWN	None	Number of hourly values included in BTUDHWSM.
BTUCLGN	None	Number of hourly values included in BTUCLGSM.
MOAT	°F	Daily average outdoor air temperature, from building 811 data file.
COUNT	None	Count of hourly data points included in daily total.
OATAV	°F	Daily average outdoor air temperature, average of buildings 811, 812, and 813, from outdoor air temperature file.
MOATAV	°F	Daily average outdoor air temperature, building 811, from outdoor air temperature file.
NOATAV	°F	Daily average outdoor air temperature, building 812, from outdoor air temperature file.
OOATAV	°F	Daily average outdoor air temperature, building 813, from outdoor air temperature file.
OATN	None	Number of hourly values included in OATAV.
MOATN	None	Number of hourly values included in MOATAV.
NOATN	None	Number of hourly values included in NOATAV.
OOATN	None	Number of hourly values included in OOATAV.
BTUHTM	BTU	Total daily heating consumption, sum of BTU1SM, BTU2SM and BTU3SM.
TALLMAV	°F	Average of T1EAV, T1WAV, T2EAV, T2WAV, T3EAV, T3WAV, and TMHAV.

The variable names listed above are those used for building 811. Buildings 812 and 813 used similar names, except that an N or an O was added to the name for buildings 812 and 813, respectively.

Data Included If: Heating > 50,000 BTU,
Daily Average Outdoor Air Temperature < = 65°F,
Date after 8/25/86, and
For building 811, date not 1/2/87.

The SPSS/PC+ system file is read from
file d:\n\sys\nbas1.sys
The file was created on 8/19/88 at 9:14:59
and is titled L-Shaped - N - Replaced Data
The SPSS/PC+ system file contains
632 cases, each consisting of
35 variables (including system variables).
35 variables will be used in this session.

This procedure was completed at 14:36:19
The raw data or transformation pass is proceeding
177 cases are written to the uncompressed active file.

Number of Valid Observations (Listwise) = 163.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31784.38	63.28	31679.00	31918.00	177	
ELNSM	682.88	58.58	476.53	821.13	177	
GASNSM	34207038	11098490.1	4627275	58032260	177	
BTU3NSM	927000.51	672482.62	-152732	2499657	177	
BTU2NSM	5630361.1	2202906.78	114527.9	9661266	177	
BTU1NSM	5630924.0	3051058.72	253931.8	11008842	177	
BTUDHWNS	2579942.6	541405.83	868496.5	3813281	177	
BTUCLGNS	-577396.0	290908.61	-1203635	378354.9	177	
T1ENAV	77.77	3.11	65.82	84.90	177	
T1WNAV	78.07	4.68	67.20	88.89	177	
T2ENAV	78.52	3.14	69.09	84.11	177	
T2WNAV	77.16	4.35	68.66	89.21	177	
T3ENAV	76.32	2.93	68.02	81.57	177	
T3WNAV	75.46	5.22	65.60	90.71	177	
TMHNAV	76.79	4.15	64.80	88.24	177	
ELNN	24.00	.00	24.00	24.00	177	
GASNN	24.00	.00	24.00	24.00	177	
BTU3NN	24.00	.00	24.00	24.00	177	
BTU2NN	24.00	.00	24.00	24.00	177	
BTU1NN	24.00	.00	24.00	24.00	177	
BTUDHWNN	24.00	.00	24.00	24.00	177	
BTUCLGNN	24.00	.00	24.00	24.00	177	
NOAT	41.04	10.16	11.60	65.12	177	
COUNT	23.78	.42	23	24	177	
OATAV	39.77	10.08	11.41	63.05	177	
MOATAV	38.56	10.51	10.59	61.57	170	
NOATAV	41.09	10.14	11.60	65.12	177	
OOATAV	38.85	10.02	11.15	62.93	170	
OATN	23.77	.42	23	24	177	
MOATN	21.67	5.95	0	24	177	
NOATN	23.67	.47	23	24	177	
OOATN	21.90	5.59	0	24	177	
BTUHTN	12188286	5007612.59	368459.7	22289010	177	
TALLNAV	77.16	3.53	67.54	84.31	177	

This procedure was completed at 14:36:45

* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

N of Cases = 177

Correlation, Covariance:

	BTUHTN	OATAV	TALLNAV	BTUDHWNS
BTUHTN	1.000 25076183841013	-.754 -38031040.265	.395 6979885.883	.201 544035631712.64
OATAV	-.754 -38031040.265	1.000 101.571	.137 4.855	-.163 -888642.193
TALLNAV	.395 6979885.883	.137 4.855	1.000 12.427	.117 223527.726
BTUDHWNS	.201 544035631712.64	-.163 -888642.193	.117 223527.726	1.000 293120277094.91

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUHTN

Beginning Block Number 1. Method: Enter OATAV TALLNAV BTUDHWNS

Variable(s) Entered on Step Number 1.. BTUDHWNS
2.. TALLNAV
3.. OATAV

Multiple R	.90611		
R Square	.82103	R Square Change	.82103
Adjusted R Square	.81793	F Change	264.55605
Standard Error	2136723.6115	Signif F Change	.0000

F = 264.55605 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUDHWNS	.06938	.30463	-.53189	.67064	7.5007E-03	.95368	.228	.8201
TALLNAV	719929.71862	46597.78885	627956.33878	811903.09847	.50681	.96137	15.450	.0000
OATAV	-408236.2274	16405.92801	-440617.7778	-375854.6770	-.82161	.94888	-24.883	.0000
(Constant)	-27302473.42	3553879.218	-34317018.34	-20287928.49			-7.682	.0000

End Block Number 1 All requested variables entered.

```
-----------------------------------------------------------------------------
Page   7   Building 812 (86/87) - 6th Regression - BTU Heat           11/22/88

This procedure was completed at 14:36:51
The SPSS/PC+ system file is read from
    file d:\n\sys\nbas1.sys
The file was created on  8/19/88 at  9:14:59
and is titled L-Shaped - N - Replaced Data
The SPSS/PC+ system file contains
    632 cases, each consisting of
     35 variables (including system variables).
     35 variables will be used in this session.
-----------------------------------------------------------------------------
Page   8   Building 812 (87/88) - 6th Regression - BTU Heat           11/22/88

This procedure was completed at 14:36:56
The raw data or transformation pass is proceeding
    135 cases are written to the uncompressed active file.
-----------------------------------------------------------------------------
Page   9   Building 812 (87/88) - 6th Regression - BTU Heat           11/22/88


Number of Valid Observations (Listwise) =       108.00

Variable       Mean     Std Dev   Minimum   Maximum      N  Label

NDATE      32149.92       52.04  32066.00  32260.00    135
ELNSM        646.23       70.62    346.99    766.46    135
GASNSM     33059221  10336185.5   4212700  47029800    135
BTU3NSM   1168447.9   705420.41  -76196.5   2307655    135
BTU2NSM   5737943.7  2802421.36  150559.7  10288930    135
BTU1NSM   6738175.9  3539960.28       .00  10816812    135
BTUDHWNS  2158458.8   501197.14  308156.2   3225652    135
BTUCLGNS    -110.33      166.14   -484.34       .00    135
T1ENAV        79.10        3.41     68.57     84.29    135
T1WNAV        79.82        4.73     67.02     87.83    135
T2ENAV        77.73        3.04     68.74     83.01    135
T2WNAV        75.64        3.57     67.79     84.99    135
T3ENAV        76.72        2.90     68.75     82.35    135
T3WNAV        73.28        3.38     66.83     81.08    135
TMHNAV        76.87        4.17     67.38     85.27    135
ELNN          24.00         .00     24.00     24.00    135
GASNN         24.00         .00     24.00     24.00    135
BTU3NN        24.00         .00     24.00     24.00    135
BTU2NN        24.00         .00     24.00     24.00    135
BTU1NN        24.00         .00     24.00     24.00    135
BTUDHWNN      24.00         .00     24.00     24.00    135
BTUCLGNN      24.00         .00     24.00     24.00    135
NOAT          35.90       11.27     10.16     56.43    135
COUNT         23.87         .33        23        24    135
OATAV         36.05       10.84     12.24     56.27    135
MOATAV        36.41       10.39     14.64     56.05    127
NOATAV        35.94       11.29     10.16     56.27    135
OOATAV        37.21       10.93      8.14     56.88    109
OATN          23.85         .36        23        24    135
MOATN         21.23        6.67         0        24    135
NOATN         23.81         .40        23        24    135
OOATN         17.19       10.11         0        24    135
BTUHTN     13644567  6882207.36  150559.7  23053367    135
TALLNAV       77.02        2.86     68.46     80.56    135
-----------------------------------------------------------------------------
Page  10   Building 812 (87/88) - 6th Regression - BTU Heat           11/22/88

This procedure was completed at 14:37:22
```

Page 11 Building 812 (87/88) - 6th Regression - BTU Heat 11/22/88

* * * * M U L T I P L E   R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

N of Cases = 135

Correlation, Covariance:

	BTUHTN	OATAV	TALLNAV	BTUDHWNS
BTUHTN	1.000 47364778106238	-.763 -56954775.015	.558 10982001.522	.350 1206665342473.4
OATAV	-.763 -56954775.015	1.000 117.544	-.101 -3.144	-.340 -1847461.354
TALLNAV	.558 10982001.522	-.101 -3.144	1.000 8.165	.153 219405.090
BTUDHWNS	.350 1206665342473.4	-.340 -1847461.354	.153 219405.090	1.000 251198569274.01

Page 12 Building 812 (87/88) - 6th Regression - BTU Heat 11/22/88

* * * * M U L T I P L E   R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUHTN

Beginning Block Number 1. Method: Enter OATAV TALLNAV BTUDHWNS

Variable(s) Entered on Step Number 1.. BTUDHWNS
2.. TALLNAV
3.. OATAV

Multiple R	.90422		
R Square	.81762	R Square Change	.81762
Adjusted R Square	.81344	F Change	195.75980
Standard Error	2972579.2640	Signif F Change	.0000

F = 195.75980 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUDHWNS	.51476	.54925	-.57178	1.60131	.03749	.87017	.937	.3504
TALLNAV	1159718.3163	91072.52904	979555.12556	1339881.5071	.48149	.97377	12.734	.0000
OATAV	-445427.1125	25221.37423	-495321.0081	-395533.2168	-.70170	.88191	-17.661	.0000
(Constant)	-60735322.36	7126211.103	-74832668.11	-46637976.60			-8.523	.0000

End Block Number 1 All requested variables entered.

Page 13 Building 812 (87/88) - 6th Regression - BTU Heat 11/22/88

This procedure was completed at 14:37:27

```
The SPSS/PC+ system file is read from
    file d:\o\sys\obas1.sys
The file was created on  8/18/88 at 14:27:00
and is titled L-Shaped - O - Replaced Data
The SPSS/PC+ system file contains
    584 cases, each consisting of
     35 variables (including system variables).
     35 variables will be used in this session.
```



```
This procedure was completed at 14:48:55
The raw data or transformation pass is proceeding
    196 cases are written to the uncompressed active file.
```


Number of Valid Observations (Listwise) = 190.00

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	31803.49	66.44	31686.00	31915.00	196	
ELOSM	601.18	30.43	512.86	667.33	196	
GASOSM	31316041	7183653.73	12298200	46308800	196	
BTU3OSM	383386.34	635077.48	.00	2094241	196	
BTU2OSM	3673405.3	1477476.80	39243.01	7235829	196	
BTU1OSM	5930563.0	2266924.54	671572.0	10819161	196	
BTUDHWOS	2571335.8	613224.51	1158197	3925908	196	
BTUCLGOS	41573.16	93177.23	.00	395969.8	196	
T1EOAV	77.78	2.71	65.05	89.80	196	
T1WOAV	78.08	2.85	69.88	88.52	196	
T2EOAV	76.00	2.63	64.70	84.54	196	
T2WOAV	78.18	3.22	66.01	86.28	196	
T3EOAV	73.93	3.35	63.29	83.73	196	
T3WOAV	75.98	3.59	67.02	84.37	196	
TMHOAV	74.06	5.64	63.38	88.82	196	
ELON	24.00	.00	24.00	24.00	196	
GASON	24.00	.00	24.00	24.00	196	
BTU3ON	24.00	.00	24.00	24.00	196	
BTU2ON	24.00	.00	24.00	24.00	196	
BTU1ON	24.00	.00	24.00	24.00	196	
BTUDHWON	24.00	.00	24.00	24.00	196	
BTUCLGON	24.00	.00	24.00	24.00	196	
OOAT	41.06	12.05	11.15	65.16	196	
COUNT	23.84	.37	23	24	196	
OATAV	41.30	11.82	11.41	64.84	196	
MOATAV	40.16	12.24	10.59	64.11	190	
NOATAV	42.50	11.73	11.60	65.39	196	
OOATAV	41.12	12.07	11.15	65.50	196	
OATN	23.84	.37	23	24	196	
MOATN	21.73	5.74	0	24	196	
NOATN	23.32	2.32	2	24	196	
OOATN	23.63	.49	22	24	196	
BTUHTO	9987354.7	3823943.26	837605.8	18951419	196	
TALLOAV	76.29	2.95	66.22	85.85	196	

This procedure was completed at 14:49:22

Page 5 Building 813 (86/87) - 6th Regression - BTU Heat 11/22/88

**** MULTIPLE REGRESSION ****

Listwise Deletion of Missing Data

N of Cases = 196

Correlation, Covariance:

	BTUHTO	OATAV	TALLOAV	BTUDHWOS
BTUHTO	1.000 14622542058514	-.830 -37526391.150	-.392 -4418162.463	.213 499434890737.57
OATAV	-.830 -37526391.150	1.000 139.783	.729 25.398	-.229 -1660637.710
TALLOAV	-.392 -4418162.463	.729 25.398	1.000 8.675	-.165 -297430.101
BTUDHWOS	.213 499434890737.57	-.229 -1660637.710	-.165 -297430.101	1.000 376044301737.92

Page 6 Building 813 (86/87) - 6th Regression - BTU Heat 11/22/88

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. BTUHTO

Beginning Block Number 1. Method: Enter OATAV TALLOAV BTUDHWOS

Variable(s) Entered on Step Number
1.. BTUDHWOS
2.. TALLOAV
3.. OATAV

Multiple R	.88685		
R Square	.78651	R Square Change	.78651
Adjusted R Square	.78317	F Change	235.77375
Standard Error	1780620.2928	Signif F Change	.0000

F = 235.77375 Signif F = .0000

------------------------------------ Variables in the Equation ------------------------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUDHWOS	.14333	.21362	-.27801	.56468	.02299	.94752	.671	.5030
TALLOAV	591010.90087	63281.86777	466193.96680	715827.83494	.45522	.46803	9.339	.0000
OATAV	-374144.8999	15974.25577	-405652.4659	-342637.3338	-1.15679	.45584	-23.422	.0000
(Constant)	-20014694.21	4423532.565	-28739654.33	-11289734.09			-4.525	.0000

End Block Number 1 All requested variables entered.

```
-------------------------------------------------------------------------------
Page   7   Building 813 (86/87) - 6th Regression - BTU Heat           11/22/88

This procedure was completed at 14:49:28
The SPSS/PC+ system file is read from
    file d:\o\sys\obas1.sys
The file was created on  8/18/88 at 14:27:00
and is titled L-Shaped - 0 - Replaced Data
The SPSS/PC+ system file contains
    584 cases, each consisting of
     35 variables (including system variables).
     35 variables will be used in this session.
-------------------------------------------------------------------------------
Page   8   Building 813 (87/88) - 6th Regression - BTU Heat           11/22/88

This procedure was completed at 14:49:31
The raw data or transformation pass is proceeding
    126 cases are written to the uncompressed active file.
-------------------------------------------------------------------------------
Page   9   Building 813 (87/88) - 6th Regression - BTU Heat           11/22/88


Number of Valid Observations (Listwise) =       125.00
```

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
NDATE	32166.71	60.93	32071.00	32260.00	126	
ELOSM	596.98	55.60	429.71	714.16	126	
GASOSM	29214703	8670432.62	8240000	46535400	126	
BTU3OSM	434150.88	627333.64	-53457.2	2036385	126	
BTU2OSM	3074732.7	2000892.60	-138694	7349898	126	
BTU1OSM	5810104.2	2351095.83	679395.0	10405000	126	
BTUDHWOS	1696766.8	456259.34	717176.2	2914026	126	
BTUCLGOS	.00	.00	.00	.00	126	
T1EOAV	74.47	3.60	67.06	84.88	126	
T1WOAV	76.82	3.28	66.98	83.37	126	
T2EOAV	76.07	2.69	69.09	80.99	126	
T2WOAV	76.17	2.67	67.51	81.36	126	
T3EOAV	72.80	3.02	66.75	79.18	126	
T3WOAV	75.28	3.25	66.12	82.66	126	
TMHOAV	74.07	5.43	59.26	83.32	126	
ELON	24.00	.00	24.00	24.00	126	
GASON	24.00	.00	24.00	24.00	126	
BTU3ON	24.00	.00	24.00	24.00	126	
BTU2ON	24.00	.00	24.00	24.00	126	
BTU1ON	24.00	.00	24.00	24.00	126	
BTUDHWON	24.00	.00	24.00	24.00	126	
BTUCLGON	24.00	.00	24.00	24.00	126	
OOAT	39.85	11.15	12.85	59.64	126	
COUNT	23.77	.42	23	24	126	
OATAV	39.42	11.40	12.24	59.78	126	
MOATAV	39.28	11.07	14.64	58.25	125	
NOATAV	39.31	11.70	10.16	61.45	126	
OOATAV	39.91	11.19	12.85	59.64	126	
OATN	23.77	.42	23	24	126	
MOATN	22.96	3.52	0	24	126	
NOATN	22.90	3.28	1	24	126	
OOATN	23.67	.47	23	24	126	
BTUHTO	9318987.7	4406707.54	1367389	17754898	126	
TALLOAV	75.10	2.61	67.84	80.67	126	

```
-------------------------------------------------------------------------------
Page  10   Building 813 (87/88) - 6th Regression - BTU Heat           11/22/88

This procedure was completed at 14:49:55
```

* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

N of Cases = 126

Correlation, Covariance:

	BTUHTO	OATAV	TALLOAV	BTUDHWOS
BTUHTO	1.000 19419071370893	-.815 -40981914.488	.024 278343.822	.304 611173497477.66
OATAV	-.815 -40981914.488	1.000 130.072	.412 12.261	-.283 -1472696.968
TALLOAV	.024 278343.822	.412 12.261	1.000 6.792	-.186 -221148.212
BTUDHWOS	.304 611173497477.66	-.283 -1472696.968	-.186 -221148.212	1.000 208172584834.07

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUHTO

Beginning Block Number 1. Method: Enter OATAV TALLOAV BTUDHWOS

Variable(s) Entered on Step Number 1.. BTUDHWOS
2.. TALLOAV
3.. OATAV

Multiple R	.91284		
R Square	.83328	R Square Change	.83328
Adjusted R Square	.82918	F Change	203.25752
Standard Error	1821298.6733	Signif F Change	.0000

F = 203.25752 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	Tolerance	T	Sig T
BTUDHWOS	1.09124	.37343	.35200	1.83049	.11298	.91413	2.922	.0041
TALLOAV	750658.97821	68830.77734	614401.57464	886916.38178	.44396	.82464	10.906	.0000
OATAV	-373473.8772	16113.41831	-405371.9993	-341575.7550	-.96658	.78576	-23.178	.0000
(Constant)	-34180655.30	5074049.458	-44225243.37	-24136067.24			-6.736	.0000

End Block Number 1 All requested variables entered.

This procedure was completed at 14:50:00

APPENDIX C:

ADDITIONAL POTENTIAL DEPENDENT VARIABLES AND SAMPLE CALCULATIONS FOR PREDICTED ENERGY CONSUMPTION

Regression Results for Other Dependent Variables

The first regression step was to run multiple regressions for all dependent variables, allowing SPSS to select the best independent variables to include in the regression equation. Addition of a variable was one step in a multistep process. The tables below show the dependent variables, other than those for which models were developed, with the independent variables selected by SPSS. Below each independent variable is the R^2 value for the equation, using the independent variables listed to that point. In other words, the R^2 for the first variable listed applies to the one-variable equation developed using that variable alone.

To develop models for a building type, it is necessary to identify variables that have good predictive power for all buildings of the type. Good predictive power for some buildings of a type, but poor power for others, is inadequate for good model development.

L-Shaped Barracks

Building 812

Cooling:	DHW .541

Building 813

Cooling:	T2E .409

DHW is domestic hot water energy consumption.
T2E is space temperature on the east side of the 2nd floor.

Calculation of Range on Predicted Energy Consumption

This is an example calculation of the high and low estimates of predicted energy consumption. The data below are from building 633, Motor Repair Shop. OAT and BayT are the daily average outdoor air and bay area temperatures. Elec is the daily total consumption of electricity. Pred Gas and Gas SE are the predicted gas value and the standard error for each data point, as calculated by SPSS. The bin data used in the calculation of Annual Energy Consumption was added to the actual building data set supplied to SPSS. Because the bin data points did not have gas consumption values, they were not used in the calculation of the regression line. SPSS did, however, include them in the calculation of predicted gas consumption and standard error of the estimate values for each data point. These values are shown below as Pred Gas and Gas SE.

The calculation of a range on the annual total consumption uses the square root of the sum of the squares of the standard errors. For the bin data set, each hour at the given bin temperature is treated as an individual case. For each temperature, the Pred Gas value is multiplied by the October through May hours at that temperature (Annual Consump). Also, Standard Error (Gas SE) is squared (SE Sqrd), then multiplied by the number of hours at that temperature (AnnSE^2). All the Annual Consump and Ann SE^2 values are summed. The sum of the Annual Consump values is divided by 1000 for readability. The square root of the sum of the Ann SE^2 values is found, multiplied by the t-statistic, and also divided by 1000 for consistency.

The value of the t-statistic is a function of the percentage confidence desired and the number of cases used in the regression. The t-statistic used is 1.96, and is for an infinite sample size and 97.5 percent (one-tailed) probability (in order to find the 95 percent two-tailed confidence limit).

The Annual Consumption Prediction of 1589 MBtu is shown in line 1 on the next page. The uncertainty value of 12.9 MBtu is shown in line 3. Thus, the Annual Consumption will be between 1576 and 1601 MBtu. The uncertainty is 0.8 percent of the predicted value.

OAT	BayT	Elec	Pred Gas	Gas SE	SE Sqrd	Oct thru May Hours	Annual Consump	Ann SE^2	
62	68.88	56.97	84560.21	472564.1	2.2E+11	299	1053479.	2.8E+12	
57	68.88	56.97	3082074.	356049.8	1.3E+11	394	50597386	2.1E+12	
52	68.88	56.97	4134703.	250676.8	6.3E+10	527	90791197	1.4E+12	
47	68.88	56.97	5187332.	177536.0	3.2E+10	627	1.4E+08	8.2E+11	
42	68.88	56.97	6239961.	181140.6	3.3E+10	668	1.7E+08	9.1E+11	
37	68.88	56.97	7292590.	258297.4	6.7E+10	657	2.0E+08	1.8E+12	
32	68.88	56.97	8345220.	365015.0	1.3E+11	672	2.3E+08	3.7E+12	
27	68.88	56.97	9397849.	482044.7	2.3E+11	582	2.3E+08	5.6E+12	
22	68.88	56.97	10450478	603416.0	3.6E+11	438	1.9E+08	6.6E+12	
17	68.88	56.97	11503107	726957.7	5.3E+11	242	1.2E+08	5.3E+12	
12	68.88	56.97	12555736	851725.8	7.3E+11	137	71672330	4.1E+12	
7	68.88	56.97	13608365	977250.7	9.6E+11	80	45361219	3.2E+12	
2	68.88	56.97	14660995	1103274.	1.2E+12	46	28100240	2.3E+12	
-3	68.88	56.97	15713624	1229642.	1.5E+12	20	13094686	1.3E+12	
-8	68.88	56.97	16766253	1356260.	1.8E+12	11	7684532.	8.4E+11	
-13	68.88	56.97	17818882	1483062.	2.2E+12	3	2227360.	2.7E+11	
-18	68.88	56.97	18871511	1610006.	2.6E+12	2	1572625.	2.2E+11	
-23	68.88	56.97	19924140	1737060.	3.0E+12	0	0	0	
-28	68.88	56.97	20976769	1864202.	3.5E+12	0	0	0	
							1.6E+09	4.3E+13	
							1589262.	12911.76	0.008124

1. Sum of Annual Predicted Gas Consumption Values, divided by 1000: 1589262

2. Sum of Squares of Standard Errors, times Annual Hours: 4.3E+13

3. Square Root of line 2, divided by 1000, multiplied by t-statistic: 12912

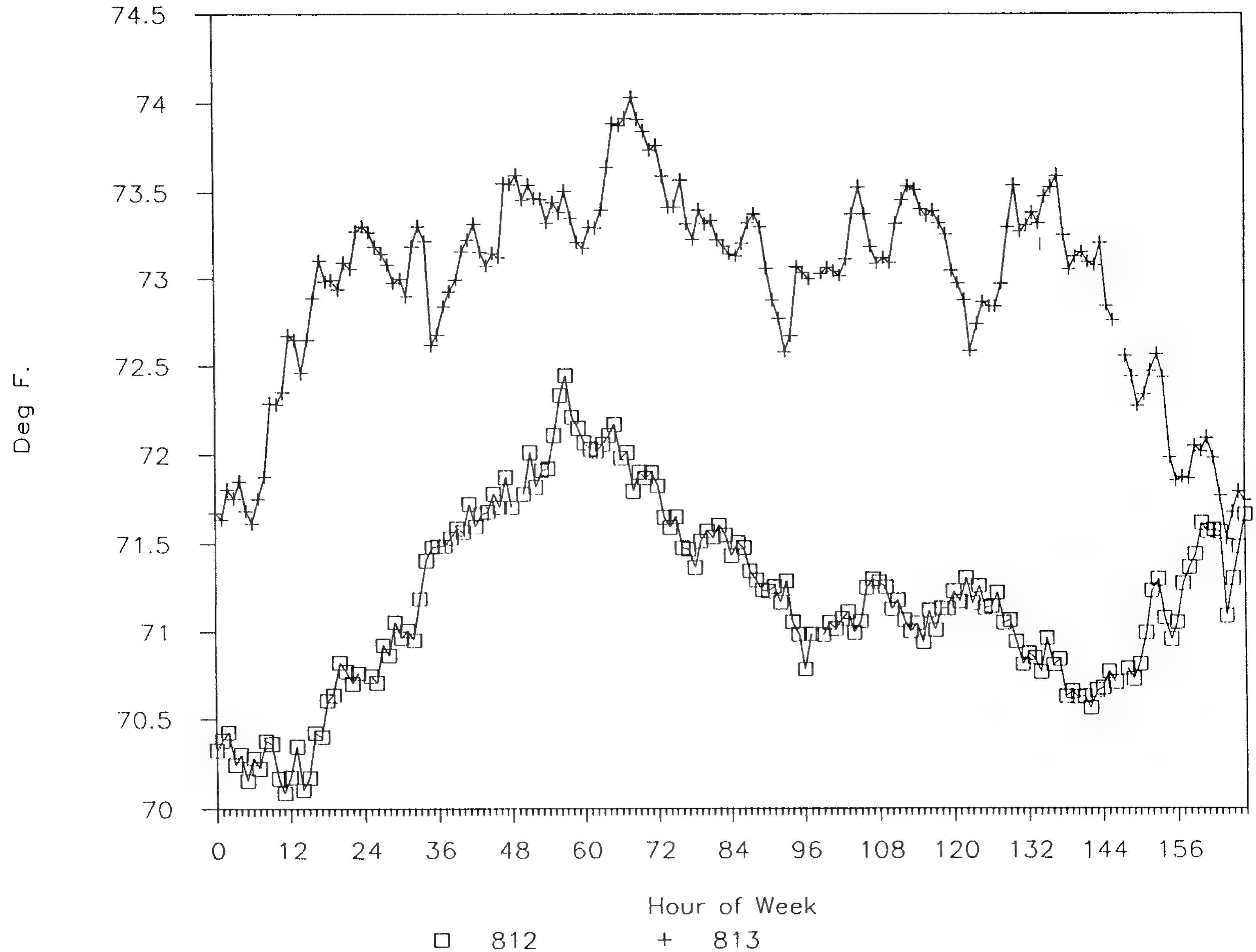
APPENDIX D:

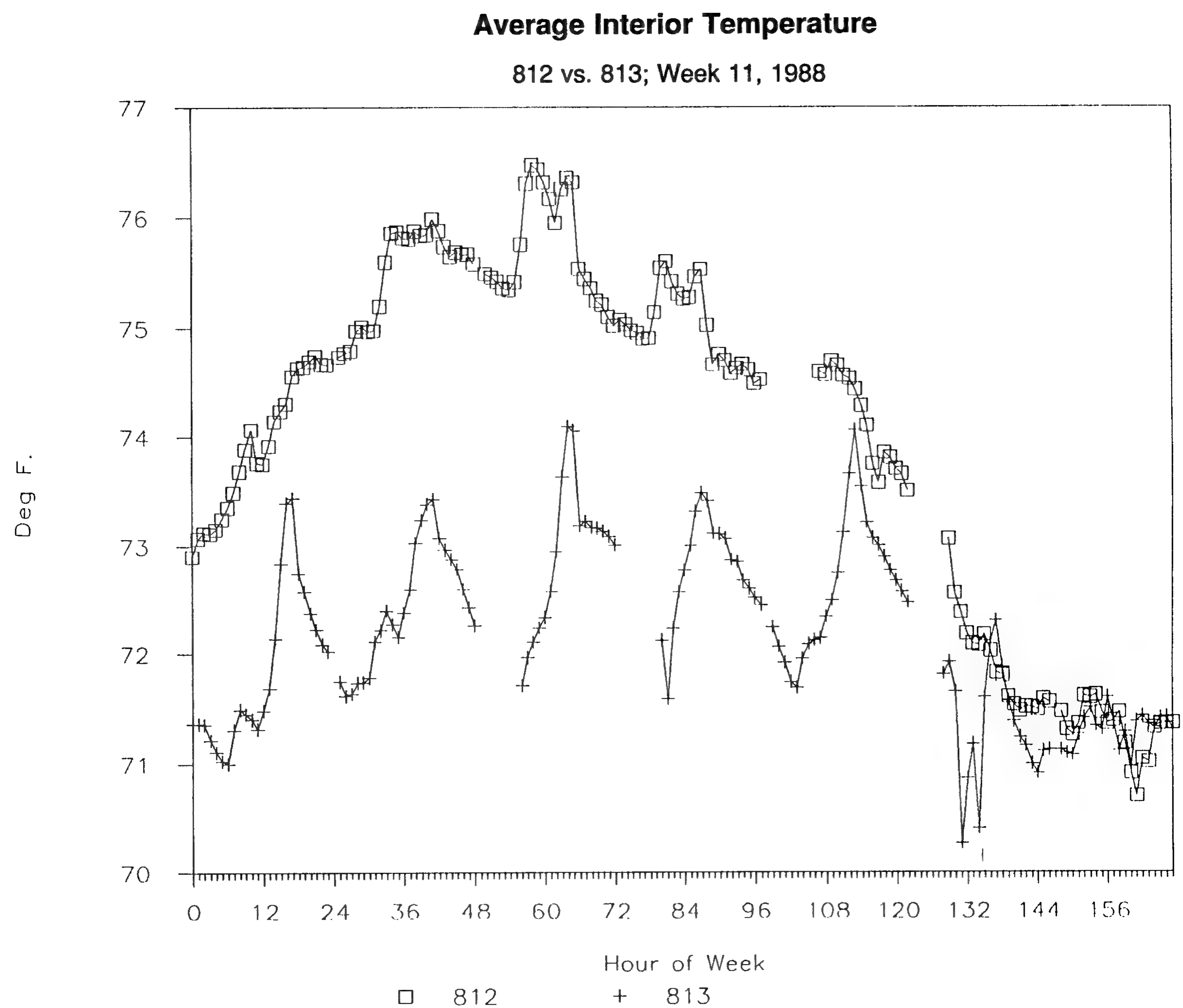
RESULTS OF 2-WEEK TEST PERIOD FOR IMPROVED BUILDING OPERATIONS

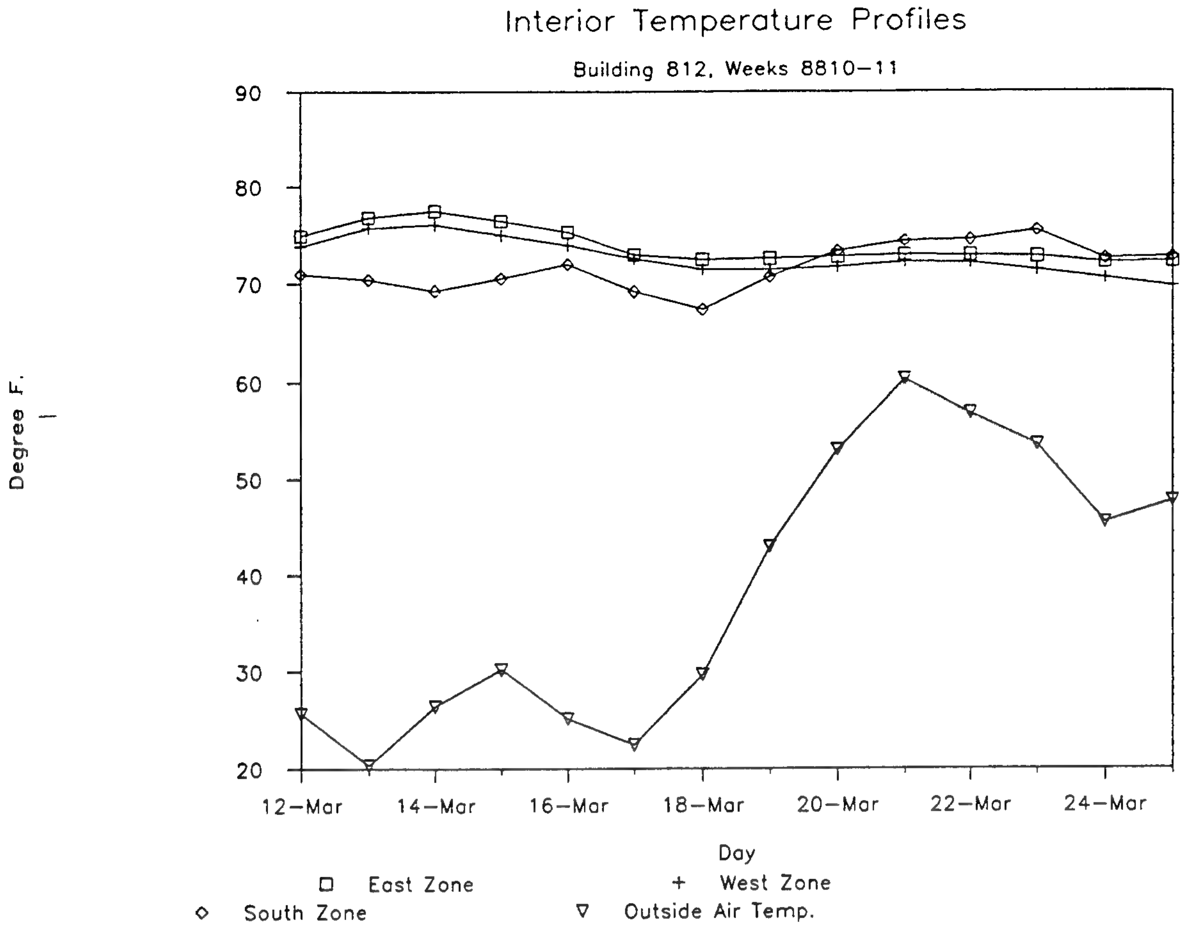
During weeks 10 and 11 of 1988, the two barracks were monitored continually and every effort was made to reduce the interior space temperatures to provide reasonable occupant comfort and comparable temperatures within both barracks. Plots of the interior temperature profiles for each side and floor as well as the average interior temperatures are included in this appendix. Tables of direct comparison energy performance data for the two barracks are also included in this appendix. No correction was required for heating degree days since both buildings' data were gathered simultaneously.

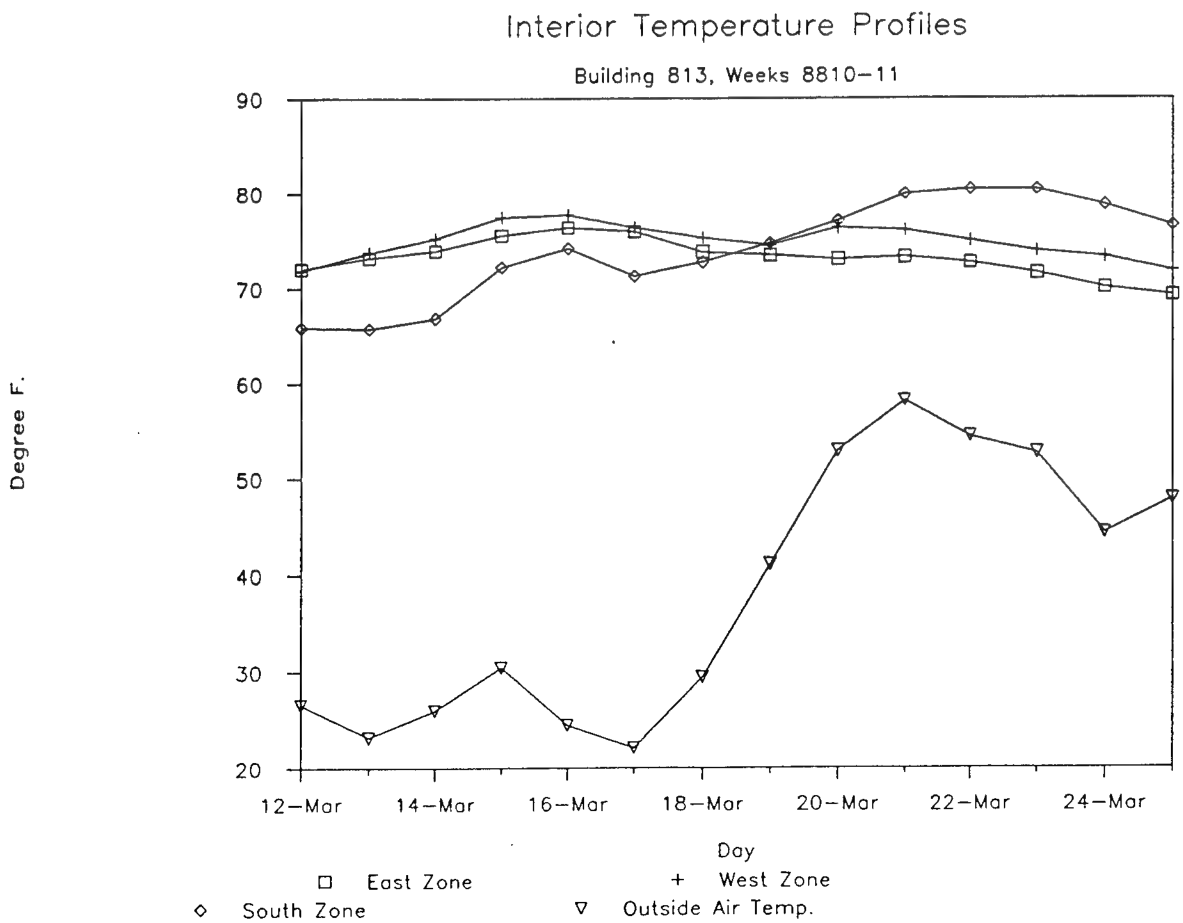
Average Interior Temperature

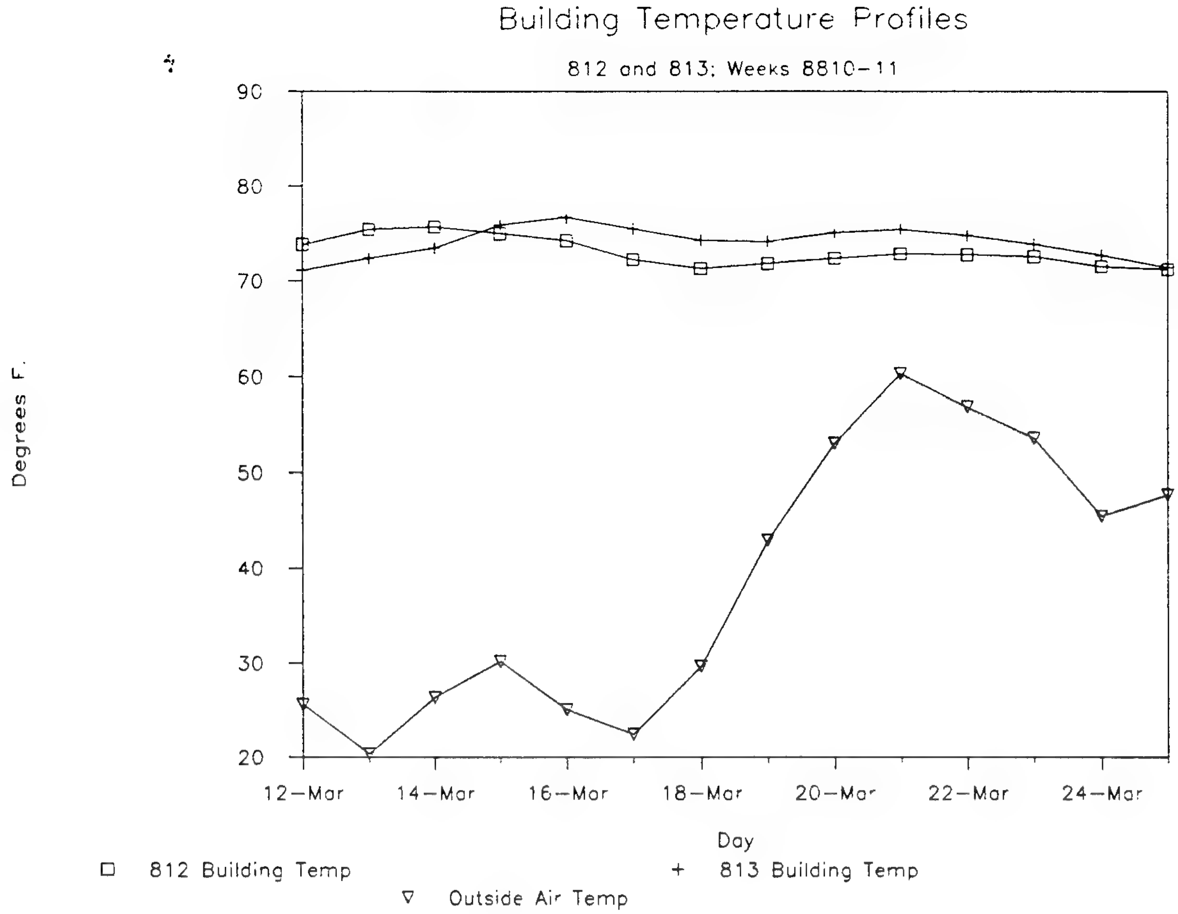
812 vs. 813; Week 10, 1988

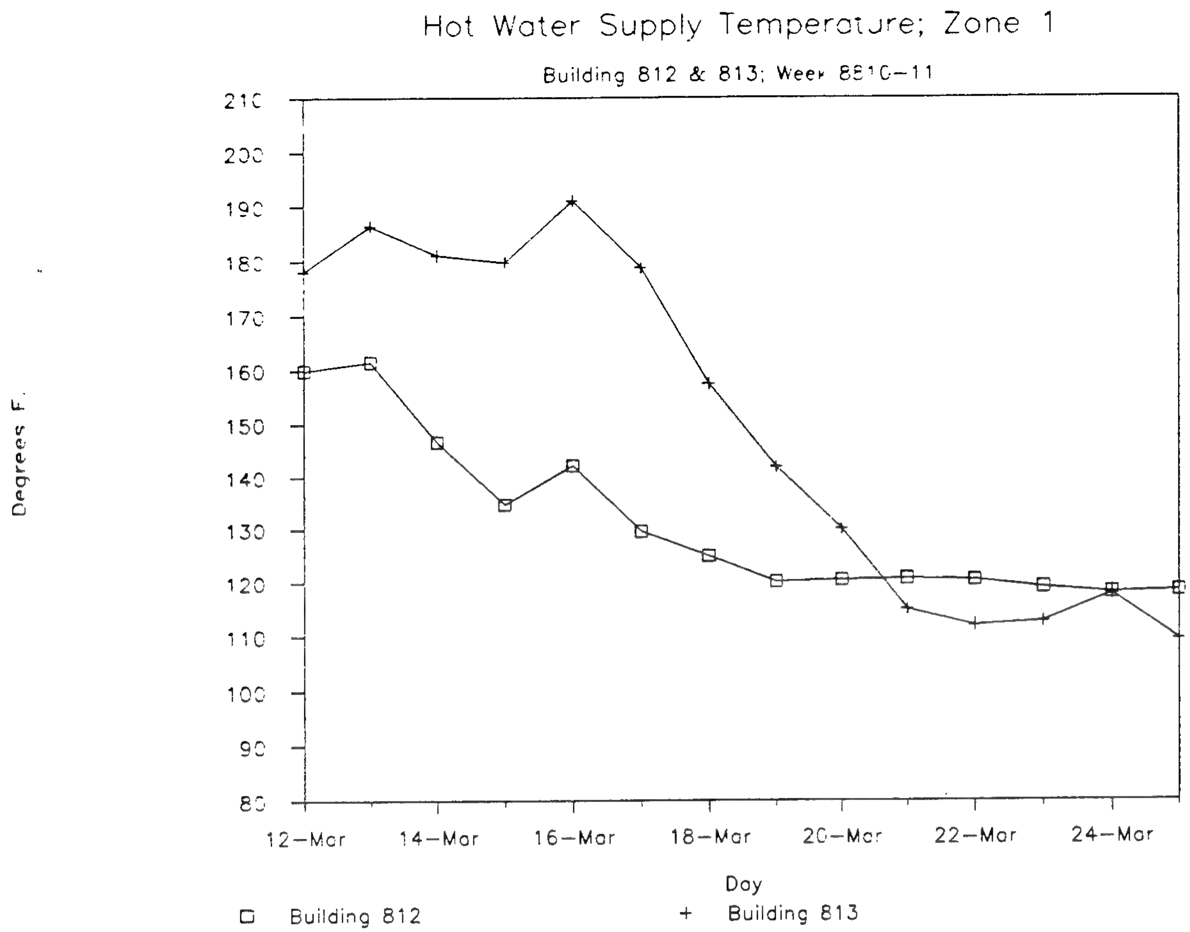


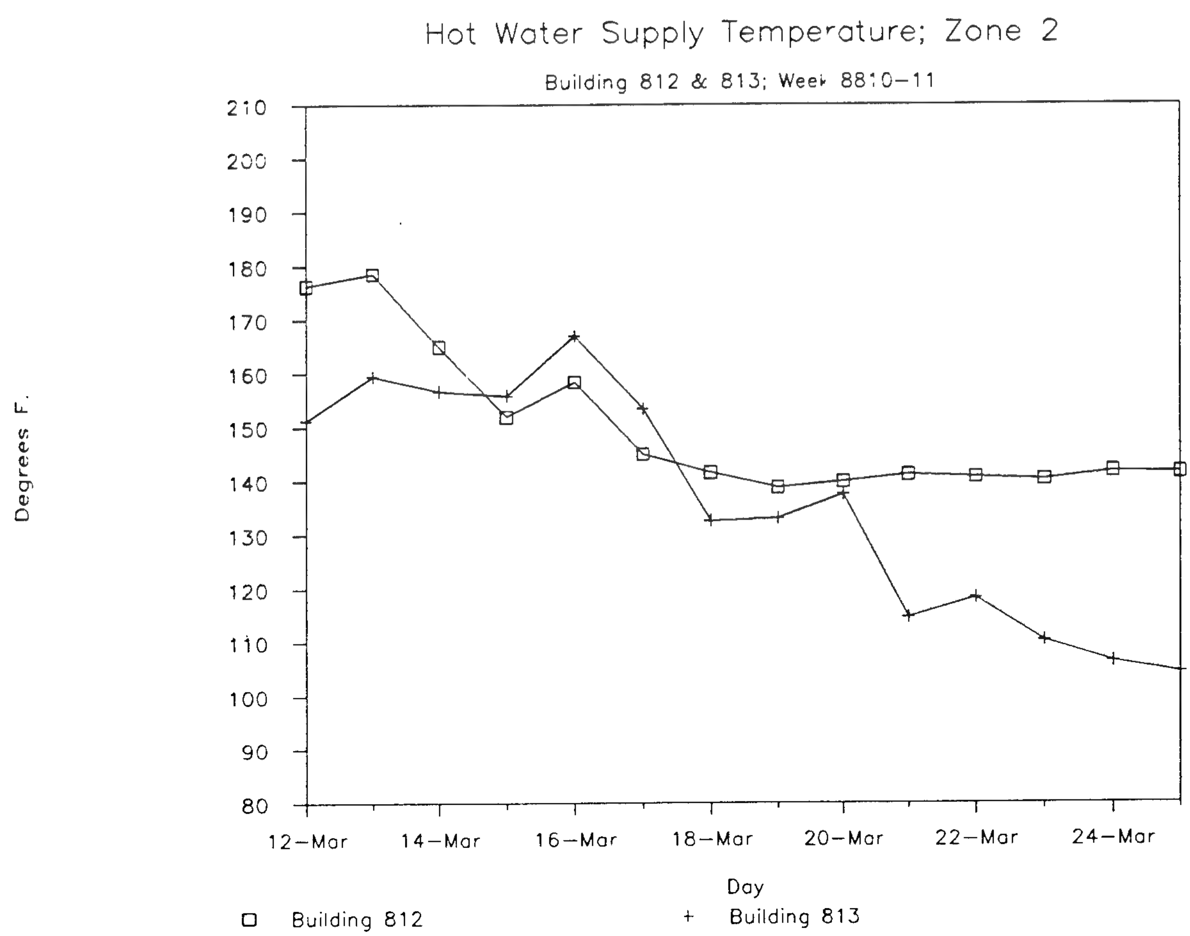

Average Interior Temperature
812 vs. 813; Week 11, 1988
Deg F.
77
76
75
74
73
72
71
70
0
12
24
36
48
60
72
84
96
108
120
132
144
156
Hour of Week
812
813

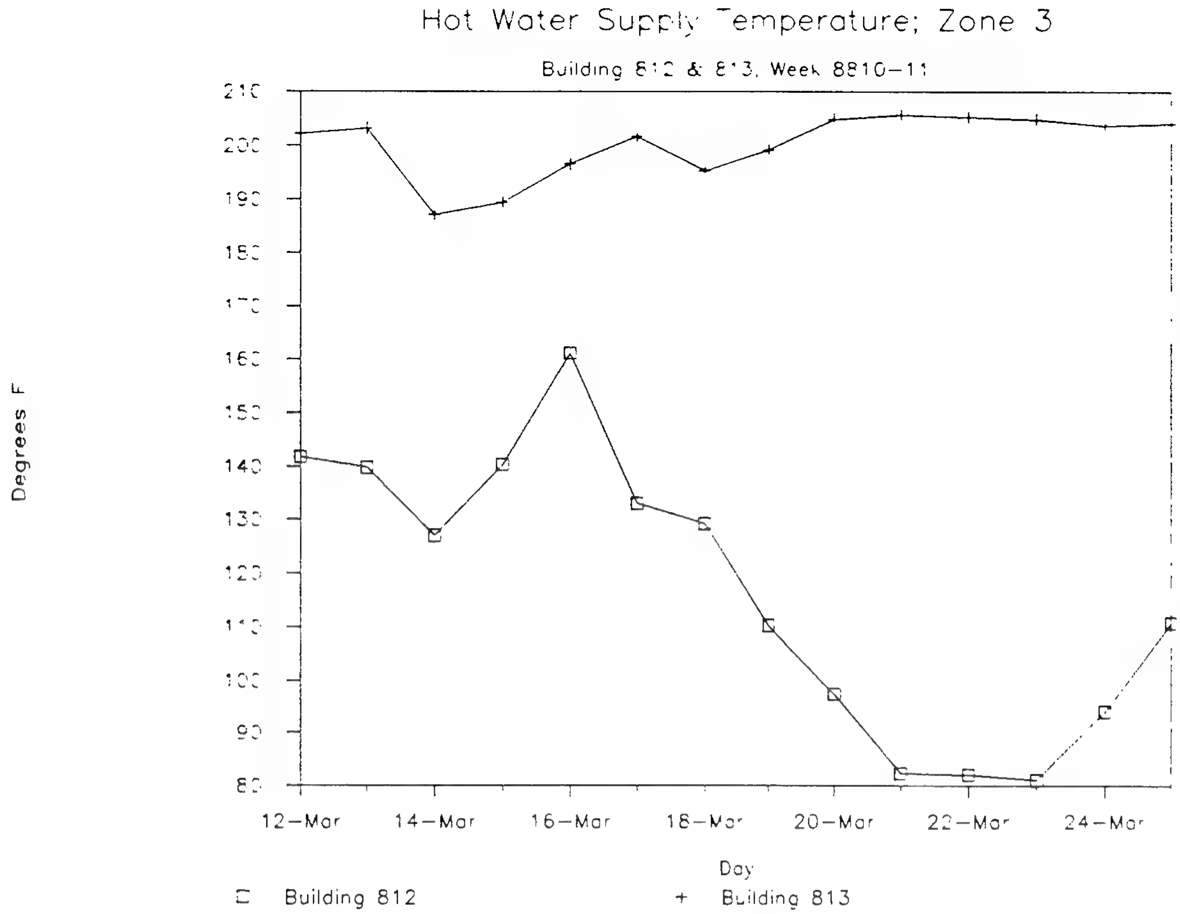

Interior Temperature Profiles
Building 812, Weeks 8810-11
Degree F.
90
80
70
60
50
40
30
20
12-Mar
14-Mar
16-Mar
18-Mar
20-Mar
22-Mar
24-Mar
Day
East Zone
West Zone
South Zone
Outside Air Temp.


Interior Temperature Profiles
Building 813, Weeks 8810-11
Degree F.
90
80
70
60
50
40
30
20
12-Mar
14-Mar
16-Mar
18-Mar
20-Mar
22-Mar
24-Mar
Day
East Zone
West Zone
South Zone
Outside Air Temp.


Building Temperature Profiles
812 and 813; Weeks 8810-11
Degrees F.
90
80
70
60
50
40
30
20
12-Mar
14-Mar
16-Mar
18-Mar
20-Mar
22-Mar
24-Mar
Day
812 Building Temp
813 Building Temp
Outside Air Temp


Hot Water Supply Temperature; Zone 1
Building 812 & 813; Week 8810-11
Degrees F.
210
200
190
180
170
160
150
140
130
120
110
100
90
80
12-Mar
14-Mar
16-Mar
18-Mar
20-Mar
22-Mar
24-Mar
Day
Building 812
Building 813


Hot Water Supply Temperature; Zone 2
Building 812 & 813; Week 8810-11
Degrees F.
210
200
190
180
170
160
150
140
130
120
110
100
90
80
12-Mar
14-Mar
16-Mar
18-Mar
20-Mar
22-Mar
24-Mar
Day
Building 812
Building 813



Hot Water Supply Temperature; Zone 3
Building 812 & 813, Week 8810-11
Degrees F
210
200
190
180
170
160
150
140
130
120
110
100
90
80
12-Mar
14-Mar
16-Mar
18-Mar
20-Mar
22-Mar
24-Mar
Day
Building 812
Building 813

Building 812 vs 813 Test / Reference --
Direct Comparison of Total Site Energy Consumption.

Energy Type	Date	Data Summary: Bldg 812 MBTU	Data Summary: Bldg 813 MBTU	Energy Saved: Energy 812 vs 813 MBTU	Energy per Square Foot: Bldg 812 MBTU	Energy per Square Foot: Bldg 813 MBTU	Savings/ Sq.Ft.: 812 vs 813 KBTU	Percent Savings: 812 vs 813 (%)
Gas Btus	8743-8809:	4885.01	5285.13	400.12	128.55	139.08	10.53	7.6%
	8810:	204.33	257.39	53.05	5.38	6.77	1.40	20.6%
	8811:	103.95	131.84	27.89	2.74	3.47	0.73	21.2%
	8810-8811 Total:	308.28	389.22	80.94	8.11	10.24	2.13	20.8%
Zone 3 Heat	8743-8809:	184.07	643.49	459.43	11.83	41.35	29.52	71.4%
	8810:	8.09	8.91	0.82	0.52	0.57	0.05	9.2%
	8811:	1.66	0.93	-0.72	0.11	0.06	-0.05	-77.4%
	8810-8811 Total:	9.75	9.85	0.10	0.63	0.63	0.01	1.0%
Zone 2 Heat	8743-8809:	878.85	466.44	-412.41	56.48	29.98	-26.50	-88.4%
	8810:	41.35	30.94	-10.42	2.66	1.99	-0.67	-33.7%
	8811:	4.84	1.31	-3.53	0.31	0.08	-0.23	-268.7%
	8810-8811 Total:	46.19	32.25	-13.95	2.97	2.07	-0.90	-43.2%
Zone 1 Heat	8743-8809:	1068.51	1060.74	-7.77	155.35	154.22	-1.13	-0.7%
	8810:	36.49	52.88	16.39	5.31	7.69	2.38	31.0%
	8811:	3.54	23.40	19.86	0.51	3.40	2.89	84.9%
	8810-8811 Total:	40.03	76.28	36.25	5.82	11.09	5.27	47.5%
Elec	8743-8809:	301.50	354.20	52.70	7.93	9.32	1.39	14.9%
	8810:	14.65	14.76	0.11	0.39	0.39	0.00	0.7%
	8811:	11.34	13.50	2.16	0.30	0.36	0.06	16.0%
	8810-8811 Total:	26.00	28.26	2.26	0.68	0.74	0.06	8.0%
DHW	8743-8809:	293.87	252.70	-41.18	7.73	6.65	-1.08	-16.3%
	8810:	17.55	15.06	-2.49	0.46	0.40	-0.07	-16.5%
	8811:	14.17	13.20	-0.97	0.37	0.35	-0.03	-7.3%
	8810-8811 Total:	31.72	28.26	-3.46	0.83	0.74	-0.09	-12.2%
Gas & Elec	8743-8809:	5186.51	5639.33	452.81	136.49	148.40	11.92	8.0%
	8810:	218.99	272.15	53.16	5.76	7.16	1.40	19.5%
	8811:	115.29	145.34	30.04	3.03	3.82	0.79	20.7%
	8810-8811 Total:	334.28	417.48	83.20	8.80	10.99	2.19	19.9%
Zone 1&2 Heat	8743-8809:	1947.35	1527.18	-420.18	62.57	49.07	-13.50	-27.5%
	8810:	77.84	83.81	5.97	2.50	2.69	0.19	7.1%
	8811:	8.38	24.72	16.33	0.27	0.79	0.52	66.1%
	8810-8811 Total:	86.23	108.53	22.30	2.77	3.49	0.72	20.6%
All Zones Heat	8743-8809:	2131.42	2170.67	39.25	56.09	57.12	1.03	1.8%
	8810:	85.93	92.73	6.79	2.26	2.44	0.18	7.3%
	8811:	10.04	25.65	15.61	0.26	0.68	0.41	60.9%
	8810-8811 Total:	95.97	118.38	22.40	2.53	3.12	0.59	18.9%

Key

Floor Space	38000	Sq. Ft. -- Elec, Gas & DHW (each)
	15561	Sq. Ft. -- Zones 1 & 2 (each)
	6878	Sq. Ft. -- Zone 3

Building 812 == Test
Building 813 == Reference

1 KBtu == 10^3 Btu
1 MBtu == 10^6 Btu

Week 8743 Starts 10/31/87
Week 8809 Starts 3/05/88
Week 8810 Starts 3/12/88
Week 8811 Starts 3/19/88

Building 812 vs 813 Test / Reference --
Direct Comparison of Average Weekly Site Energy Consumption.

Energy Type	Date	Data Summary: Bldg 812 MBTU	Data Summary: Bldg 813 MBTU	Energy Saved: Energy 812 vs 813 MBTU	Energy per Square Foot: Bldg 812 MBTU	Energy per Square Foot: Bldg 813 MBTU	Savings/ Sq.Ft.: 812 vs 813 KBTU	Percent Savings: 812 vs 813 (%)
Gas Btus	8743-8809:	257.11	278.16	21.06	6.77	7.32	0.55	7.6%
	8810:	204.33	257.39	53.05	5.38	6.77	1.40	20.6%
	8811:	103.95	131.84	27.89	2.74	3.47	0.73	21.2%
	8810-8811 Total:	154.14	194.61	40.47	4.06	5.12	1.06	20.8%
Zone 3	8743-8809:	9.69	33.87	24.18	0.25	0.89	0.64	71.4%
Heat	8810:	8.09	8.91	0.82	0.21	0.23	0.02	9.2%
	8811:	1.66	0.93	-0.72	0.04	0.02	-0.02	-77.4%
	8810-8811 Total:	4.87	4.92	0.05	0.13	0.13	0.00	1.0%
Zone 2	8743-8809:	46.26	24.55	-21.71	1.22	0.65	-0.57	-88.4%
Heat	8810:	41.35	30.94	-10.42	1.09	0.81	-0.27	-33.7%
	8811:	4.84	1.31	-3.53	0.13	0.03	-0.09	-268.7%
	8810-8811 Total:	23.10	16.12	-6.97	0.61	0.42	-0.18	-43.2%
Zone 1	8743-8809:	56.24	55.83	-0.41	1.48	1.47	-0.01	-0.7%
Heat	8810:	36.49	52.88	16.39	0.96	1.39	0.43	31.0%
	8811:	3.54	23.40	19.86	0.09	0.62	0.52	84.9%
	8810-8811 Total:	20.02	38.14	18.12	0.53	1.00	0.48	47.5%
Elec	8743-8809:	15.87	18.64	2.77	0.42	0.49	0.07	14.9%
	8810:	14.65	14.76	0.11	0.39	0.39	0.00	0.7%
	8811:	11.34	13.50	2.16	0.30	0.36	0.06	16.0%
	8810-8811 Total:	13.00	14.13	1.13	0.34	0.37	0.03	8.0%
DHW	8743-8809:	15.47	13.30	-2.17	0.41	0.35	-0.06	-16.3%
	8810:	17.55	15.06	-2.49	0.46	0.40	-0.07	-16.5%
	8811:	14.17	13.20	-0.97	0.37	0.35	-0.03	-7.3%
	8810-8811 Total:	15.86	14.13	-1.73	0.42	0.37	-0.05	-12.2%
Gas & Elec	8743-8809:	272.97	296.81	23.83	7.18	7.81	0.63	8.0%
	8810:	218.99	272.15	53.16	5.76	7.16	1.40	19.5%
	8811:	115.29	145.34	30.04	3.03	3.82	0.79	20.7%
	8810-8811 Total:	167.14	208.74	41.60	4.40	5.49	1.09	19.9%
Zone 1&2	8743-8809:	102.49	80.38	-22.11	2.70	2.12	-0.58	-27.5%
Heat	8810:	77.84	83.81	5.97	2.05	2.21	0.16	7.1%
	8811:	8.38	24.72	16.33	0.22	0.65	0.43	66.1%
	8810-8811 Total:	43.11	54.26	11.15	1.13	1.43	0.29	20.6%
All Zones	8743-8809:	112.18	114.25	2.07	2.95	3.01	0.05	1.8%
Heat	8810:	85.93	92.73	6.79	2.26	2.44	0.18	7.3%
	8811:	10.04	25.65	15.61	0.26	0.68	0.41	60.9%
	8810-8811 Total:	47.99	59.19	11.20	1.26	1.56	0.29	18.9%

Key

Floor Space 38000 Sq. Ft. -- Elec, Gas & DHW (each)
15561 Sq. Ft. -- Zones 1 & 2 (each)
6878 Sq. Ft. -- Zone 3

Building 812 == Test
Building 813 == Reference

1 KBtu == 10^3 Btu
1 MBtu == 10^6 Btu

Week 8743 Starts 10/31/87
Week 8809 Starts 3/05/88
Week 8810 Starts 3/12/88
Week 8811 Starts 3/19/88

Building 812 vs 813 Test / Reference --
Direct Comparison of Normalized Weekly Site Energy Consumption.

Energy Type	Date	Data Summary: Bldg 812 KBTU/HDD	Data Summary: Bldg 813 KBTU/HDD	Energy Saved: Energy 812 vs 813 KBTU/HDD	Energy per Square Foot: Bldg 812 KBTU/HDD SQ.FT.	Energy per Square Foot: Bldg 813 KBTU/HDD SQ.FT.	Savings/ Sq.Ft.: 812 vs 813 KBTU/HDD	Percent Savings: 812 vs 813 (%)
Gas Btus	8743-8809:	1120.47	1212.24	91.77	29.49	31.90	2.42	7.6%
	8810:	686.60	864.87	178.27	18.07	22.76	4.69	20.6%
	8811:	957.17	1213.96	256.79	25.19	31.95	6.76	21.2%
	8810-8811 Total:	758.94	958.20	199.26	19.97	25.22	5.24	20.8%
Zone 3 Heat	8743-8809:	42.22	147.60	105.38	1.11	3.88	2.77	71.4%
	8810:	27.19	29.95	2.76	0.72	0.79	0.07	9.2%
	8811:	15.26	8.60	-6.66	0.40	0.23	-0.18	-77.4%
	8810-8811 Total:	24.00	24.24	0.24	0.63	0.64	0.01	1.0%
Zone 2 Heat	8743-8809:	201.58	106.99	-94.59	5.30	2.82	-2.49	-88.4%
	8810:	138.95	103.95	-35.00	3.66	2.74	-0.92	-33.7%
	8811:	44.60	12.10	-32.50	1.17	0.32	-0.86	-268.7%
	8810-8811 Total:	113.72	79.39	-34.33	2.99	2.09	-0.90	-43.2%
Zone 1 Heat	8743-8809:	245.08	243.30	-1.78	6.45	6.40	-0.05	-0.7%
	8810:	122.61	177.68	55.06	3.23	4.68	1.45	31.0%
	8811:	32.60	215.50	182.89	0.86	5.67	4.81	84.9%
	8810-8811 Total:	98.55	187.79	89.24	2.59	4.94	2.35	47.5%
Elec	8743-8809:	69.15	81.24	12.09	1.82	2.14	0.32	14.9%
	8810:	49.24	49.60	0.36	1.30	1.31	0.01	0.7%
	8811:	104.46	124.33	19.87	2.75	3.27	0.52	16.0%
	8810-8811 Total:	64.01	69.58	5.58	1.68	1.83	0.15	8.0%
DHW	8743-8809:	67.41	57.96	-9.44	1.77	1.53	-0.25	-16.3%
	8810:	58.96	50.59	-8.37	1.55	1.33	-0.22	-16.5%
	8811:	130.48	121.56	-8.92	3.43	3.20	-0.23	-7.3%
	8810-8811 Total:	78.08	69.57	-8.52	2.05	1.83	-0.22	-12.2%
Gas & Elec	8743-8809:	1189.62	1293.48	103.86	31.31	34.04	2.73	8.0%
	8810:	735.85	914.47	178.63	19.36	24.07	4.70	19.5%
	8811:	1061.63	1338.29	276.65	27.94	35.22	7.28	20.7%
	8810-8811 Total:	822.95	1027.78	204.84	21.66	27.05	5.39	19.9%
Zone 1&2 Heat	8743-8809:	446.66	350.29	-96.38	11.75	9.22	-2.54	-27.5%
	8810:	261.56	281.63	20.06	6.88	7.41	0.53	7.1%
	8811:	77.20	227.59	150.39	2.03	5.99	3.96	66.1%
	8810-8811 Total:	212.27	267.18	54.91	5.59	7.03	1.44	20.6%
All Zones Heat	8743-8809:	488.88	497.88	9.00	12.87	13.10	0.24	1.8%
	8810:	288.75	311.58	22.82	7.60	8.20	0.60	7.3%
	8811:	92.46	236.20	143.73	2.43	6.22	3.78	60.9%
	8810-8811 Total:	236.27	291.42	55.15	6.22	7.67	1.45	18.9%

Key

Floor Space	38000	Sq. Ft. - 0.00
	15561	Sq. Ft. -- Zones 1 & 2 (each)
	6878	Sq. Ft. -- Zone 3

Building 812 == Test
Building 813 == Reference

1 KBtu == 10^3 Btu
1 MBtu == 10^6 Btu

Week 8743 Starts 10/31/87	HDD:	8743-8809:	4359.8
Week 8809 Starts 3/05/88		8810:	297.6
Week 8810 Starts 3/12/88		8811:	108.6
Week 8811 Starts 3/19/88			

APPENDIX E:

CURRENT AND PROJECT YEAR COST ESTIMATES

This appendix contains the reconstructed cost estimates for installing the EIFS on a type 64 (L-shaped) barracks at Fort Carson, CO. The estimates were developed using Dodge System Unit Cost Data and appropriate labor rates for the Colorado Springs region. The current year was assumed to be FY89 and the project year was 1986. Also included in this appendix is an excerpt from the Corps of Engineers unit cost data for maintenance and repair. The specific page included details the costs of painting, maintenance, and repair of block construction (CMU) walls on three-story building exteriors. Frequency and labor costs are included in this table and were used to estimate the cost avoidance due to the EIFS retrofit.

Building 812 Cost Estimate
Current Year (FY89)

Description	Number of Units	Unit of Measure	$/Unit Labor	Region Adjust	$/Unit Material	Region Adjust	Total Cost
1. 1" Insul/Crete Insul Sys	2092	sf	2.31	1	1.6	1	8179.72
2. 2" Insul/Crete Insul Sys	12824	sf	2.31	1	1.75	1	52065.44
3. Copper Roof Flashing	316	sf	1.63	0.88	1.94	1.18	1176.657
4. Paint Downspouts	343	lf	0.56	0.88	0.15	1.18	229.7414
5. Paint Gutters	784	lf	0.56	0.88	0.15	1.18	525.1232
6. Paint Louvers	50	sf	0.84	0.88	0.22	1.18	49.94
7. Paint Concr Window Ledg	8100	sf	0.32	0.88	0.18	1.18	4001.4
							66228.02

Building 812 Cost Estimate
Project Year (FY86)

Description	Number of Units	Unit of Measure	$/Unit Labor	Region Adjust	$/Unit Material	Region Adjust	Total Cost
1. 1" Insul/Crete Insul Sys	2092	sf	2.07	1	1.78	1	8054.2
2. 2" Insul/Crete Insul Sys	12824	sf	2.07	1	1.96	1	51680.72
3. Copper Roof Flashing	316	sf	1.55	0.93	4.94	1.17	2281.93
4. Paint Downspouts	343	lf	1.27	1	0.11	1	473.34
5. Paint Gutters	784	lf	1.27	1	0.11	1	1081.92
6. Paint Louvers	50	sf	1.41	1	0.11	1	76
7. Paint Concr Window Ledg	8100	sf	0.36	0.93	0.18	1.17	4417.74
							68065.85

UM=Unit of Measure TRD=Trade Index Class=Task Classification TWPMTH=Task Work Performace Method

CAECES	DESCRIPTION	UM	TRD	CLASS	HIGH FREQ	AVE FREQ	LOW FREQ	LABOR HOURS	MATERIAL COSTS	EQUIPMENT HOURS	TWPMTH
0415725	REPLC.PNTD.STRUCT.CLAY TILE EXT.2ND FL.	2	16	1	499.00	500.00	501.00	.234650	9.060000	.117325	ICIIII
0415726	REFN.RPLC.PNT.STRUC.CLAY TILE EXT.2ND FL	2	5	1	499.00	500.00	501.00	.053170	.080000	.053170	CCIIII
5 3	0415730 STRUCT. CLAY TILE (WP/P)EXT.FIN. 3RD FL.										
0415732	REPR.PNTD.STRUC.CLAY TILE EXT.3RD+FLS.	2	16	0	20.00	25.00	30.00	.030030	.181200	.030030	ICIIII
0415733	REFN.RPR.PNT.STRUC.CLAY TILE EXT.3RD+FL.	2	5	0	20.00	25.00	30.00	.026260	.001600	.026260	ICIIII
0415734	REFIN.PNTD.STRUCT.CLAY TILE EXT.3RD+FLS.	2	5	1	6.00	8.00	12.00	.059691	.060000	.059691	CCIIII
0415735	REPLC.PNTD.STRUCT.CLAY TILE EXT.3RD+FLS.	2	16	1	499.00	500.00	501.00	.267670	9.060000	.133835	ICIIII
0415736	REFN.RPLC.PNT.STRUC.CLAY TILE EXT.3RD+FL	2	5	1	499.00	500.00	501.00	.069680	.080000	.069680	CCIIII
4 8	0415800 CONCRETE BLOCK EXTERIOR FINISH										
5 1	0415810 CONCRETE BLOCK EXTERIOR FIN. 1ST FLOOR										
0415812	REPAIR CONCRETE BLOCK EXT.WALL 1ST FL.	2	16	0	20.00	25.00	30.00	.006370	.015920	.006370	ICIIII
0415815	REPLACE CONCRETE BLOCK EXT.WALL 1ST FL.	2	16	1	499.00	500.00	501.00	.201500	.796000	.100750	ICIIII
5 2	0415820 CONCRETE BLOCK EXTERIOR FIN. 2ND FLOOR										
0415822	REPAIR CONCRETE BLOCK EXT.WALL 2ND FL.	2	16	0	20.00	25.00	30.00	.021450	.015920	.021450	ICIIII
0415825	REPLACE CONCRETE BLOCK EXT.WALL 2ND FL.	2	16	1	499.00	500.00	501.00	.234650	.796000	.117325	ICIIII
5 3	0415830 CONCRETE BLOCK EXTERIOR FIN. 3RD+ FLOOR										
0415832	REPAIR CONCRETE BLOCK EXT.WALL 3RD+ FL.	2	16	0	20.00	25.00	30.00	.030030	.015920	.030030	ICIIII
0415835	REPLACE CONCRETE BLOCK EXT.WALL 3RD FL.	2	16	1	499.00	500.00	501.00	.267670	.796000	.133835	ICIIII
4 9	0415900 CONCRETE BLOCK (WP/P) EXT. FINISH										
5 1	0415910 CONCRETE BLOCK (WP/P) EXT. FIN. 1ST FLR.										
0415912	REPR.PNTD.CONCR. BLOCK EXT.WALL 1ST FL.	2	16	0	20.00	25.00	30.00	.006370	.015920	.006370	ICIIII
0415913	RFN.RPR.PNTD.CONCR.BLOCK EXT.WALL 1ST FL	2	5	0	20.00	25.00	30.00	.003250	.001600	.003250	ICIIII
0415914	REFIN.PNTD.CONCR.BLOCK EXT.WALL 1ST FL.	2	5	1	6.00	8.00	12.00	.028249	.060000	.028249	CCIIII
0415915	REPLC.PNTD.CONCR.BLOCK EXT.WALL 1ST FL.	2	16	1	499.00	500.00	501.00	.201500	.796000	.100750	ICIIII
0415916	RFN.RPLC.PNTD.CONC.BLOCK EXT.WALL 1ST FL	2	5	1	499.00	500.00	501.00	.036530	.080000	.036530	CCIIII
5 2	0415920 CONCRETE BLOCK (WP/P) EXT. FIN. 2ND FLR.										
0415922	REPR.PNTD.CONCRETE BLOCK EXT.WALL 2ND FL	2	16	0	20.00	25.00	30.00	.021450	.015920	.021450	ICIIII
0415923	RFN.RPR.PNTD.CONC.BLOCK EXT.WALL 2ND FL.	2	5	0	20.00	25.00	30.00	.017940	.001600	.017940	ICIIII
0415924	REFIN.PNTD.CONCR. BLOCK EXT.WALL 2ND FL.	2	5	1	6.00	8.00	12.00	.044165	.060000	.044165	CCIIII
0415925	REPLC.PNTD.CONCR. BLOCK EXT.WALL 2ND FL.	2	16	1	499.00	500.00	501.00	.234650	.796000	.117325	ICIIII
0415926	RFN.RPLC.PNT.CONC.BLOCK EXT.WALL 2ND FL.	2	5	1	499.00	500.00	501.00	.053170	.080000	.053170	CCIIII
5 3	0415930 CONCRETE BLOCK (WP/P) EXT. FIN. 3RD+ FL.										
0415932	REPR.PNTD.CONCR.BLOCK EXT.WALL 3RD FL.	2	16	0	20.00	25.00	30.00	.030030	.015920	.030030	ICIIII
0415933	RFN.RPR.PNTD.CONC.BLOCK EXT.WALL 3RD+FL.	2	5	0	20.00	25.00	30.00	.026260	.001600	.026260	ICIIII
0415934	REFIN.PNTD.CONCR. BLOCK EXT.WALL 3RD+FL.	2	5	1	6.00	8.00	12.00	.059691	.060000	.059691	CCIIII
0415935	REPLC.PNTD.CONC.BLOCK.EXT.WALL 3RD+FL.	2	16	1	499.00	500.00	501.00	.267670	.796000	.133835	ICIIII
0415936	REFIN.RPLC.PNTD.CONC.BLOCK EXT.3RD+FL.	2	5	1	499.00	500.00	501.00	.069680	.080000	.069680	CCIIII
4 10	0415A00 CONCRETE EXTERIOR FINISH										
5 1	0415A10 CONCRETE EXTERIOR FINISH 1ST FLOOR										
0415A12	REPAIR CONCRETE EXT. WALL 1ST FLOOR	2	16	0	20.00	25.00	30.00	.046670	.023880	.046670	ICIIII
0415A13	REFIN.REPAIRED CONCRETE EXT.WALL 1ST FL.	2	5	0	20.00	25.00	30.00	.003250	.001600	.003250	ICIIII
0415A14	REFINISH CONCRETE EXT.WALL 1ST FLOOR	2	5	1	6.00	8.00	12.00	.028249	.060000	.028249	CCIIII
0415A15	REPLACE CONCRETE EXT.WALL 1ST FLOOR	2	16	1	499.00	500.00	501.00	3.809520	4.370000	1.904760	ICIIII
0415A16	REFIN.REPLACED CONCRETE EXT.WALL 1ST FL.	2	5	1	499.00	500.00	501.00	.036530	.080000	.036530	CCIIII
5 2	0415A20 CONCRETE EXTERIOR FINISH 2ND FLOOR										
0415A22	REPAIR CONCRETE EXT.WALL 2ND FLOOR	2	16	0	20.00	25.00	30.00	.065780	.023880	.065780	ICIIII
0415A23	REFIN.REPAIRED CONCRETE EXT.WALL 2ND FL.	2	5	0	20.00	25.00	30.00	.017940	.001600	.017940	ICIIII
0415A24	REFINISH CONCRETE EXT.WALL 2ND FLOOR	2	5	1	6.00	8.00	12.00	.044165	.060000	.044165	CCIIII
0415A25	REPLACE CONCRETE EXT. WALL - 2ND FLOOR	2	16	1	499.00	500.00	501.00	4.202510	4.370000	2.101255	ICIIII
0415A26	REFIN.REPLACED CONCRETE EXT.WALL 2ND FL.	2	5	1	499.00	500.00	501.00	.053170	.080000	.053170	CCIIII
5 3	0415A30 CONCRETE EXTERIOR FINISH 3RD+ FLOOR										
0415A32	REPAIR CONCRETE EXT. WALL 3RD+ FLOOR	2	16	0	20.00	25.00	30.00	.078260	.023880	.078260	ICIIII
0415A33	REFIN.REPAIRED CONCRETE EXT.WALL 3RD+FL.	2	5	0	20.00	25.00	30.00	.026260	.001600	.026260	ICIIII

APPENDIX F:

LIFE-CYCLE COST ANALYSIS

The life-cycle analysis summaries were generated using the Life-Cycle Cost in Design (LCCID) program. The reports included in this appendix include construction costs and fuel costs for the current year, project year using reconstructed cost estimates detailed previously in this appendix. LCCID analyses were also performed based on the actual construction costs during the project year. The labor costs for all runs have been adjusted to match labor rates in DOE Region 8 which include the Colorado Springs area.

Study B812A is for actual construction costs using 1986 energy costs and 1985 energy escalation rates. Study B812J is also for the actual construction costs using 1985 escalation rates. However, the costs savings due to reduced wall painting and maintenance have been included in the analysis. Study B812I uses 1987 escalation rates with the actual construction costs and savings resulting from reduced block wall painting and maintenance.

Studies B812E and B812K use reconstructed project year construction cost estimates with 1987 energy escalation rates. B812K includes additional costs savings due to reduced maintenance. Study B812D is similar to B812E but uses 1985 energy escalation figures. Both escalation rates were evaluated since the project year was between the two escalation rates available in the LCCID program.

Studies B812F and B812G were developed using construction cost estimates for FY89. B812F does not include nonenergy savings due to the reduced exterior painting, whereas study B812G does include these additional savings.

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: B812A
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.028
INSTALLATION & LOCATION: FT. CARSON REGION NO. 8
PROJECT NO. & TITLE: 1 BUILDING 812 ACTUAL COSTS (1985 ESC)
FISCAL YEAR 1986 DISCRETE PORTION NAME: EIFS RETROFIT
ANALYSIS DATE: 07-11-89 ECONOMIC LIFE 25 YEARS PREPARED BY: RUNDUS

1.	INVESTMENT		
	A. CONSTRUCTION COST	$	140770.
	B. SIOH	$	7743.
	C. DESIGN COST	$	8447.
	D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	141264.
	E. SALVAGE VALUE COST	-$	0.
	F. TOTAL INVESTMENT (1D-1E)	$	141264.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	10.13	0.
B. DIST	$ .00	0.	$ 0.	20.94	0.
C. RESID	$ .00	0.	$ 0.	23.25	0.
D. NAT G	$ 4.08	1279.	$ 5218.	22.69	118404.
E. COAL	$ .00	0.	$ 0.	12.26	0.
F. TOTAL		1279.	$ 5218.		$ 118404.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 11.65
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2-3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 39073.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 5218.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 118404.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .84
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 27.07

LIFE CYCLE COST ANALYSIS SUMMARY — STUDY: B812J

ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) — LCCID 1.028

INSTALLATION & LOCATION: FT. CARSON — REGION NO. 8

PROJECT NO. & TITLE: 10 BUILDING B12 ACTUAL (85 ESC. W/ PAINT

FISCAL YEAR 1986 DISCRETE PORTION NAME: EIFS RETROFIT

ANALYSIS DATE: 07-12-89 ECONOMIC LIFE 25 YEARS PREPARED BY: RUNDUS

1. INVESTMENT

A. CONSTRUCTION COST	$	140770.
B. SIOH	$	7743.
C. DESIGN COST	$	8447.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	141264.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	141264.

2. ENERGY SAVINGS (+) / COST (-)

ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	11.44	0.
B. DIST	$ .00	0.	$ 0.	16.79	0.
C. RESID	$ .00	0.	$ 0.	17.92	0.
D. NAT G	$ 4.08	1279.	$ 5218.	17.90	93408.
E. COAL	$ .00	0.	$ 0.	13.24	0.
F. TOTAL		1279.	$ 5218.		$ 93408.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-)		$ 0.
(1) DISCOUNT FACTOR (TABLE A)	11.65	
(2) DISCOUNTED SAVING/COST (3A X 3A1)		$ 0.

B. NON RECURRING SAVINGS(+) / COSTS(-)

ITEM	SAVINGS(+) COST(-) (1)	YR OC (2)	DISCNT FACTR (3)	DISCOUNTED SAVINGS(+)/ COST(-)(4)
1. PAINT YEAR 8	$ 15617.	8	.58	9058.
2. PAINT YEAR 16	$ 15617.	16	.34	5310.
3. PAINT YEAR 24	$ 15617.	24	.20	3123.
d. TOTAL	$ 46851.			17491.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 17491.

D. PROJECT NON ENERGY QUALIFICATION TEST

(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 30825.

A IF 3D1 IS = OR > 3C GO TO ITEM 4

B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F = ______

C IF 3D1B IS = > 1 GO TO ITEM 4

D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 7092.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 110899.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5)/1F)= .79

(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 19.92

LIFE CYCLE COST ANALYSIS SUMMARY — STUDY: BS.81
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) — LCCID 1.028
INSTALLATION & LOCATION: FT. CARSON — REGION NO. 8
PROJECT NO. & TITLE: 9 BUILDING 818 ACTUAL COSTS W/ PAINT
FISCAL YEAR 1986 DISCRETE PORTION NAME: EIFS RETROFIT
ANALYSIS DATE: 07-12-89 ECONOMIC LIFE 25 YEARS PREPARED BY: RUNDUS

1. INVESTMENT

A. CONSTRUCTION COST	$	140770.
B. SIOH	$	7743.
C. DESIGN COST	$	8447.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	141264.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	141264.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU (1)	SAVINGS MBTU/YR (2)	ANNUAL $ SAVINGS (3)	DISCOUNT FACTOR (4)	DISCOUNTED SAVINGS (5)
A. ELECT	$ .00	0.	$ 0.	10.13	0.
B. DIST	$ .00	0.	$ 0.	20.94	0.
C. RESID	$ .00	0.	$ 0.	23.25	0.
D. NAT G	$ 4.08	1279.	$ 5218.	22.69	118404.
E. COAL	$ .00	0.	$ 0.	12.26	0.
F. TOTAL		1279.	$ 5218.		$ 118404.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 11.65
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

B. NON RECURRING SAVINGS(+) / COSTS(-)

ITEM	SAVINGS(+) COST(-) (1)	YR OC (2)	DISCNT FACTR (3)	DISCOUNTED SAVINGS(+) COST(-)(4)
1. PAINT YEAR 8	$ 15617.	8	.58	9058.
2. PAINT YEAR 16	$ 15617.	16	.34	5310.
3. PAINT YEAR 24	$ 15617.	24	.20	3123.
d. TOTAL	$ 46851.			17491.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 17491.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 39073.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F = ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/YEARS ECONOMIC LIFE) $ 7091.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 135895.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5)/1F = .96
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 19.92

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: B812D
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.028
INSTALLATION & LOCATION: FT. CARSON REGION NO. 8
PROJECT NO. & TITLE: 4 BUILDING 812 PROJECT YEAR COST
FISCAL YEAR 1986 DISCRETE PORTION NAME: EIFS RETROFIT
ANALYSIS DATE: 07-12-89 ECONOMIC LIFE 25 YEARS PREPARED BY: RUNDUS

1. INVESTMENT

A. CONSTRUCTION COST	$	94329.
B. SIOH	$	5189.
C. DESIGN COST	$	5661.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	94671.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	94670.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	11.44	0.
B. DIST	$ .00	0.	$ 0.	16.79	0.
C. RESID	$ .00	0.	$ 0.	17.92	0.
D. NAT G	$ 4.08	1279.	$ 5218.	17.90	93408.
E. COAL	$ .00	0.	$ 0.	13.24	0.
F. TOTAL		1279.	$ 5218.		$ 93405.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
  1 DISCOUNT FACTOR (TABLE A) 11.65
  2 DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
  (1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 30825.
    A IF 3D1 IS = OR > 3C GO TO ITEM 4
    B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
    C IF 3D1B IS = > 1 GO TO ITEM 4
    D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 5218.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 93408.

6. DISCOUNTED SAVINGS RATIO (SIR)= 5 / 1F = .99
(IF < 1 PROJECT DOES NOT QUALIFY

7. SIMPLE PAYBACK PERIOD ESTIMATED SPB=1F/4 18.14

LIFE CYCLE COST ANALYSIS SUMMARY — STUDY: 89125
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) — LCCID 1.028
INSTALLATION & LOCATION: FT. CARSON — REGION NO. 8
PROJECT NO. & TITLE: 5 BLDG 812 PROJECT YR. ESTIMATE 87 ESC
FISCAL YEAR 1986 DISCRETE PORTION NAME: EIFS RETROFIT
ANALYSIS DATE: 07-12-89 ECONOMIC LIFE 25 YEARS PREPARED BY: RUNDUS

1\. INVESTMENT

A. CONSTRUCTION COST	$	94339.
B. SIOH	$	5189.
C. DESIGN COST	$	5661.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	94670.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	94670.

2\. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	10.13	0.
B. DIST	$ .00	0.	$ 0.	20.94	0.
C. RESID	$ .00	0.	$ 0.	23.25	0.
D. NAT G	$ 4.08	1279.	$ 5216.	22.69	118404.
E. COAL	$ .00	0.	$ 0.	18.26	0.
F. TOTAL		1279.	$ 5216.		$ 118404.

3\. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) — $ 0.
(1) DISCOUNT FACTOR (TABLE A — 11.65
(2) DISCOUNTED SAVING/COST (3A X 3A1) — $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS + /COST(-) (3A2+3B[illegible]) — $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) — $ 39073.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4\. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 5216.

5\. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 118404.

6\. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= 1.25
(IF < 1 PROJECT DOES NOT QUALIFY

7\. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 18.14

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: B812
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.028
INSTALLATION & LOCATION: FT. CARSON REGION NO. 8
PROJECT NO. & TITLE: 11 BLDG 812 PROJECT YEAR ESTIMATE W/PAINT
FISCAL YEAR 1986 DISCRETE PORTION NAME: EIFS RETROFIT
ANALYSIS DATE: 07-12-89 ECONOMIC LIFE 25 YEARS PREPARED BY: RUNDUS

1. INVESTMENT

A. CONSTRUCTION COST	$	94339.
B. SIOH	$	5189.
C. DESIGN COST	$	5661.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	94670.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	94670.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	10.13	0.
B. DIST	$ .00	0.	$ 0.	20.94	0.
C. RESID	$ .00	0.	$ 0.	23.25	0.
D. NAT G	$ 4.08	1279.	$ 5218.	22.69	118404.
E. COAL	$ .00	0.	$ 0.	12.26	0.
F. TOTAL		1279.	$ 5218.		$ 118404.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 11.65
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

B. NON RECURRING SAVINGS(+) / COSTS(-)

ITEM	SAVINGS(+) COST(-) (1)	YR OC (2)	DISCNT FACTR (3)	DISCOUNTED SAVINGS(+) COST(-)(4)
1. PAINT YEAR 8	$ 15617.	8	.58	9058.
2. PAINT YEAR 16	$ 15617.	16	.34	5310.
3. PAINT YEAR 24	$ 15617.	24	.20	3123.
d. TOTAL	$ 46851.			17491.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 17491.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 39073.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F = ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 7093.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 135895.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5)/1F= 1.44
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 13.35

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: B8:2F
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.028
INSTALLATION & LOCATION: FT. CARSON REGION NO. 8
PROJECT NO. & TITLE: 6 BUILDING 812 CURRENT YEAR COST ESTIMATE
FISCAL YEAR 1989 DISCRETE PORTION NAME: EIFS RETROFIT
ANALYSIS DATE: 07-12-89 ECONOMIC LIFE 25 YEARS PREPARED BY: RUNDUS

1. INVESTMENT

A. CONSTRUCTION COST	$	91794.
B. SIOH	$	5049.
C. DESIGN COST	$	5508.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	92116.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	92116.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	10.13	0.
B. DIST	$ .00	0.	$ 0.	20.94	0.
C. RESID	$ .00	0.	$ 0.	23.25	0.
D. NAT G	$ 3.11	1279.	$ 3978.	22.69	90254.
E. COAL	$ .00	0.	$ 0.	18.26	0.
F. TOTAL		1279.	$ 3978.		$ 90254.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 11.65
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 0.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 29784.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 3978.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 90254.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= .98
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 23.16

LIFE CYCLE COST ANALYSIS SUMMARY STUDY: B812G
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP) LCCID 1.026
INSTALLATION & LOCATION: FT. CARSON REGION NO. 8
PROJECT NO. & TITLE: 6 BUILDING 812 CURRENT YEAR COST ESTIMATE
FISCAL YEAR 1989 DISCRETE PORTION NAME: EIFS RETROFIT
ANALYSIS DATE: 07-12-89 ECONOMIC LIFE 25 YEARS PREPARED BY: RUNDUS

1. INVESTMENT

A. CONSTRUCTION COST	$	91794.
B. SIOH	$	5049.
C. DESIGN COST	$	5508.
D. ENERGY CREDIT CALC (1A+1B+1C)X.9	$	92116.
E. SALVAGE VALUE COST	-$	0.
F. TOTAL INVESTMENT (1D-1E)	$	92116.

2. ENERGY SAVINGS (+) / COST (-)
ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	UNIT COST $/MBTU(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELECT	$ .00	0.	$ 0.	10.13	0.
B. DIST	$ .00	0.	$ 0.	20.94	0.
C. RESID	$ .00	0.	$ 0.	23.25	0.
D. NAT G	$ 3.11	1279.	$ 3978.	22.69	90254.
E. COAL	$ .00	0.	$ 0.	12.26	0.
F. TOTAL		1279.	$ 3978.		$ 90254.

3. NON ENERGY SAVINGS(+) / COST(-)

A. ANNUAL RECURRING (+/-) $ 0.
(1) DISCOUNT FACTOR (TABLE A) 11.65
(2) DISCOUNTED SAVING/COST (3A X 3A1) $ 0.

B. NON RECURRING SAVINGS(+) / COSTS(-)

ITEM	SAVINGS(+) COST(-) (1)	YR OC (2)	DISCNT FACTR (3)	DISCOUNTED SAVINGS(+)/ COST(-)(4)
1. PAINT YEAR 8	$ 15617.	8	.58	9058.
2. PAINT YEAR 16	$ 15617.	16	.34	5310.
3. PAINT YEAR 24	$ 15617.	24	.20	3123.
d. TOTAL	$ 46851.			17491.

C. TOTAL NON ENERGY DISCOUNTED SAVINGS(+) /COST(-) (3A2+3Bd4) $ 17491.

D. PROJECT NON ENERGY QUALIFICATION TEST
(1) 25% MAX NON ENERGY CALC (2F5 X .33) $ 29784.
A IF 3D1 IS = OR > 3C GO TO ITEM 4
B IF 3D1 IS < 3C CALC SIR = (2F5+3D1)/1F)= ______
C IF 3D1B IS = > 1 GO TO ITEM 4
D IF 3D1B IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1D/(YEARS ECONOMIC LIFE)) $ 5852.

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 107745.

6. DISCOUNTED SAVINGS RATIO (SIR)=(5 / 1F)= 1.17
(IF < 1 PROJECT DOES NOT QUALIFY)

7. SIMPLE PAYBACK PERIOD (ESTIMATED) SPB=1F/4 15.74

ABBREVIATIONS

ACOE	Army Communities of Excellence
BLAST	Building Loads Analysis and System Thermodynamics (program)
CDD	Cooling degree days
CMU	concrete masonry unit
DEH	Directorate of Engineering and Housing
DHW	domestic hot water
ECA	energy conservation alternatives
ECIP	Energy Conservation Investment Program
EIFS	exterior insulation finish system
HDD	heating degree days
HVAC	heating, ventilation, and air-conditioning
LCC	life-cycle cost
LCCID	Life-Cycle Cost in Design (program)
M&R	maintenance and repair
NCO	noncommissioned officer
OAT	outside average temperature
O&M	operation and maintenance
SIOH	Supervision and Inspection Overhead
SIR	savings to investment ratio
TM	Technical Manual
TR	Technical Report
USACE	U.S. Army Corps of Engineers
USACERL	U.S. Army Construction Engineering Research Laboratory

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